



US009243392B2

(12) **United States Patent**
Marty et al.

(10) **Patent No.:** **US 9,243,392 B2**
(45) **Date of Patent:** **Jan. 26, 2016**

(54) **RESISTIVE COUPLING FOR AN
AUTOMATIC FAUCET**

(71) Applicant: **MASCO CORPORATION OF
INDIANA**, Indianapolis, IN (US)

(72) Inventors: **Garry R. Marty**, Fishers, IN (US); **Joel
D. Sawaski**, Indianapolis, IN (US); **Kurt
J. Thomas**, Indianapolis, IN (US); **Kyle
R. Davidson**, Noblesville, IN (US)

(73) Assignee: **Delta Faucet Company**, Indianapolis,
IN (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/501,869**

(22) Filed: **Sep. 30, 2014**

(65) **Prior Publication Data**

US 2015/0013064 A1 Jan. 15, 2015

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/411,603,
filed on Mar. 4, 2012, now Pat. No. 8,844,564, which is
a continuation of application No. 12/518,842, filed as
application No. PCT/US2007/025336 on Dec. 11,
2007, now Pat. No. 8,127,782, which is a
continuation-in-part of application No. 11/641,574,
filed on Dec. 19, 2006, now Pat. No. 7,690,395.

(51) **Int. Cl.**

E03C 1/05 (2006.01)
H01C 1/01 (2006.01)
H01C 13/02 (2006.01)
H01C 1/14 (2006.01)
E03C 1/04 (2006.01)

(52) **U.S. Cl.**

CPC **E03C 1/057** (2013.01); **H01C 1/01** (2013.01);
H01C 1/14 (2013.01); **H01C 13/02** (2013.01);
E03C 2001/0415 (2013.01); **Y10T 137/9464**
(2015.04)

(58) **Field of Classification Search**

CPC . E03C 1/057; E03C 1/055; E03C 2001/0415;
E03C 1/05; H01C 1/01; H01C 13/02; H01C
1/14; Y10T 137/9464
USPC 137/801; 4/623
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,991,481 A 7/1961 Book
3,081,594 A 3/1963 Atkins et al.
3,151,340 A 10/1964 Teshima
3,314,081 A 4/1967 Atkins et al.

(Continued)

FOREIGN PATENT DOCUMENTS

CA 2492226 A1 7/2005
DE 3339849 5/1985

(Continued)

OTHER PUBLICATIONS

Camacho et al., Freescale Semiconductor, "Touch Pad System Using
MC34940/MC33794 E-Field Sensors," Feb. 2006, 52 pgs.

(Continued)

Primary Examiner — Kevin Lee

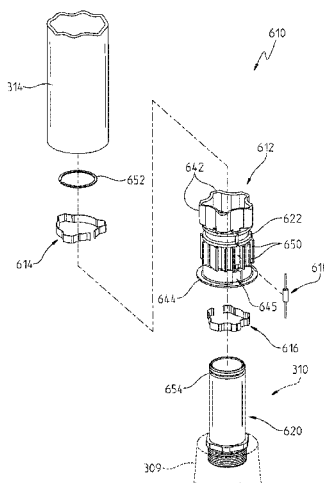
(74) *Attorney, Agent, or Firm* — Faegre Baker Daniels LLP

(57)

ABSTRACT

A faucet includes a logical control, a spout, a hub, a handle,
and a touch control operably coupled to at least one of the
spout, the hub, and the handle.

19 Claims, 27 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

3,333,160	A	7/1967	Gorski	4,909,435	A	3/1990	Kidouchi et al.
3,406,941	A	10/1968	Ichimori et al.	4,914,758	A	4/1990	Shaw
3,588,038	A	6/1971	Tanaka	4,916,613	A	4/1990	Lange et al.
3,651,989	A	3/1972	Westrich	4,917,142	A	4/1990	Laing et al.
3,685,541	A	8/1972	Braucksick et al.	4,921,211	A	5/1990	Novak et al.
3,705,574	A	12/1972	Duncan	4,923,116	A	5/1990	Homan
3,765,455	A	10/1973	Countryman	4,930,551	A	6/1990	Haws
3,799,171	A	3/1974	Patel	4,936,289	A	6/1990	Peterson
3,987,819	A	10/1976	Scheuermann	4,941,608	A	7/1990	Shimizu et al.
4,185,336	A	1/1980	Young	4,945,942	A	8/1990	Lund
4,201,518	A	5/1980	Stevenson	4,945,943	A	8/1990	Cogger
4,290,052	A	9/1981	Eichelberger et al.	4,955,535	A	9/1990	Tsutsui et al.
4,295,132	A	10/1981	Burney et al.	4,965,894	A	10/1990	Baus
4,331,292	A	5/1982	Zimmer	4,967,794	A	11/1990	Tsutsui et al.
4,337,388	A	6/1982	July	4,969,598	A	11/1990	Garris
4,359,186	A	11/1982	Kiendl	4,970,373	A	11/1990	Lutz et al.
4,406,313	A	9/1983	Bennett et al.	4,971,106	A	11/1990	Tsutsui et al.
4,407,444	A	10/1983	Knebel et al.	4,981,158	A	1/1991	Brondolino et al.
4,409,694	A	10/1983	Barrett et al.	4,985,944	A	1/1991	Shaw
4,410,791	A	10/1983	Eastep	4,995,585	A	2/1991	Gruber et al.
4,420,811	A	12/1983	Tarnay et al.	4,998,673	A	3/1991	Pilolla
4,421,269	A	12/1983	Ts'ao	5,009,572	A	4/1991	Imhoff et al.
4,424,767	A	1/1984	Wicke et al.	5,012,124	A	4/1991	Hollaway
4,429,422	A	2/1984	Wareham	5,020,127	A	5/1991	Eddas et al.
4,436,983	A	3/1984	Solobay	5,033,508	A	7/1991	Laverty
4,439,669	A	3/1984	Ryffel	5,033,715	A	7/1991	Chiang
4,450,829	A	5/1984	Morita et al.	5,040,106	A	8/1991	Maag
4,459,465	A	7/1984	Knight	5,042,524	A	8/1991	Lund
4,503,575	A	3/1985	Knoop et al.	5,056,712	A	10/1991	Enck
4,537,348	A	8/1985	Gossi	5,057,214	A	10/1991	Morris
4,541,562	A	9/1985	Zukausky	5,058,804	A	10/1991	Yonekubo et al.
4,554,688	A	11/1985	Puccerella	5,063,955	A	11/1991	Sakakibara
4,563,780	A	1/1986	Pollack	5,073,991	A	12/1991	Marty
4,567,350	A	1/1986	Todd Jr.	5,074,520	A	12/1991	Lee et al.
4,581,707	A	4/1986	Millar	5,086,526	A	2/1992	Van Marcke
4,584,463	A	4/1986	Klages et al.	5,092,560	A	3/1992	Chen
4,604,515	A	8/1986	Davidson	5,095,945	A	3/1992	Jensen
4,606,325	A	8/1986	Lujan	5,105,846	A	4/1992	Britt
4,611,757	A	9/1986	Saether	5,124,934	A	6/1992	Kawamoto et al.
4,628,902	A	12/1986	Comber	5,125,433	A	6/1992	DeMoss et al.
4,638,147	A	1/1987	Dytch et al.	5,129,034	A	7/1992	Sydenstricker
4,674,678	A	6/1987	Knebel et al.	5,133,089	A	7/1992	Tsutsui et al.
4,680,446	A	7/1987	Post	5,139,044	A	8/1992	Otten et al.
4,682,581	A	7/1987	Laing et al.	5,143,049	A	9/1992	Laing et al.
4,682,728	A	7/1987	Oudenhoven et al.	5,148,824	A	9/1992	Wilson et al.
4,688,277	A	8/1987	Kakinoki et al.	5,170,361	A	12/1992	Reed
4,700,884	A	10/1987	Barrett et al.	5,170,514	A	12/1992	Weigert
4,700,885	A	10/1987	Knebel	5,170,816	A	12/1992	Schnieders
4,709,728	A	12/1987	Ying-Chung	5,170,944	A	12/1992	Shirai
4,713,525	A	12/1987	Eastep	5,174,495	A	12/1992	Eichholz et al.
4,716,605	A	1/1988	Shepherd et al.	5,175,892	A	1/1993	Shaw
4,735,357	A	4/1988	Gregory et al.	5,183,029	A	2/1993	Ranger
4,738,280	A	4/1988	Oberholtzer	5,184,642	A	2/1993	Powell
4,742,456	A	5/1988	Kamena	5,187,816	A	2/1993	Chiou
4,750,472	A	6/1988	Fazekas	5,202,666	A	4/1993	Knippscheer
4,753,265	A	6/1988	Barrett et al.	5,205,318	A	4/1993	Massaro et al.
4,756,030	A	7/1988	Juliver	5,206,963	A	5/1993	Wiens
4,757,943	A	7/1988	Sperling et al.	5,217,035	A	6/1993	Van Marcke
4,761,839	A	8/1988	Ganaway	5,224,509	A	7/1993	Tanaka et al.
4,762,273	A	8/1988	Gregory et al.	5,224,685	A	7/1993	Chiang et al.
4,768,705	A	9/1988	Tsutsui et al.	5,243,717	A	9/1993	Yasuo
4,786,782	A	11/1988	Takai et al.	D340,279	S	10/1993	Mattis
4,798,224	A	1/1989	Haws	5,257,341	A	10/1993	Austin et al.
4,808,793	A	2/1989	Hurko	5,261,443	A	11/1993	Walsh
4,832,259	A	5/1989	Vandermeyden	5,262,621	A	11/1993	Hu et al.
4,845,316	A	7/1989	Kaercher	5,265,318	A	11/1993	Shero
4,854,498	A	8/1989	Stayton	5,277,219	A	1/1994	Lund
4,869,287	A	9/1989	Pepper et al.	5,281,808	A	1/1994	Kunkel
4,869,427	A	9/1989	Kawamoto et al.	5,287,570	A	2/1994	Peterson et al.
4,870,986	A	10/1989	Barrett et al.	5,309,940	A	5/1994	Delabie et al.
4,872,485	A	10/1989	Laverty	5,315,719	A	5/1994	Tsutsui et al.
4,875,623	A	10/1989	Garris	5,322,086	A	6/1994	Sullivan
4,893,653	A	1/1990	Ferrigno	5,323,803	A	6/1994	Blumenauer
4,896,658	A	1/1990	Yonekubo et al.	5,325,822	A	7/1994	Fernandez
4,901,915	A	2/1990	Sakakibara	5,334,819	A	8/1994	Lin
				5,341,839	A	8/1994	Kobayashi et al.
				5,351,347	A	10/1994	Kunkel
				5,351,712	A	10/1994	Houlihan
				5,358,177	A	10/1994	Cashmore

(56)

References Cited

U.S. PATENT DOCUMENTS

5,361,215	A	11/1994	Tompkins et al.	5,961,095	A	10/1999	Schrott
5,362,026	A	11/1994	Kobayashi et al.	5,963,624	A	10/1999	Pope
5,385,168	A	1/1995	Lund	5,966,753	A	10/1999	Gauthier et al.
5,397,099	A	3/1995	Pilolla	5,973,417	A	10/1999	Goetz et al.
5,400,961	A	3/1995	Tsutsui et al.	5,979,776	A	11/1999	Williams
5,408,578	A	4/1995	Bolivar	5,983,922	A	11/1999	Laing et al.
5,419,930	A	5/1995	Schucker	5,988,593	A	11/1999	Rice
5,429,272	A	7/1995	Luigi	6,000,170	A	12/1999	Davis
5,437,003	A	7/1995	Blanco	6,003,170	A	12/1999	Humpert et al.
RE35,018	E	8/1995	Homan	6,003,182	A	12/1999	Song
5,438,642	A	8/1995	Posen	6,006,784	A	12/1999	Tsutsui et al.
5,467,967	A	11/1995	Gillooly	6,019,130	A	2/2000	Rump
5,479,558	A	12/1995	White et al.	6,026,844	A	2/2000	Laing et al.
5,482,250	A	1/1996	Kodaira	6,029,094	A	2/2000	Diffut
5,504,306	A	4/1996	Russell et al.	6,032,616	A	3/2000	Jones
5,504,950	A	4/1996	Natalizia et al.	6,042,885	A	3/2000	Woollard et al.
5,511,579	A	4/1996	Price	6,059,192	A	5/2000	Zosimadis
5,511,723	A	4/1996	Eki et al.	6,061,499	A	5/2000	Hlebovy
3,254,313	A	5/1996	Atkins et al.	6,075,454	A	6/2000	Yamasaki
5,540,555	A	7/1996	Corso et al.	6,082,407	A	7/2000	Paterson et al.
5,549,273	A	8/1996	Aharon	6,101,452	A	8/2000	Krall et al.
5,550,753	A	8/1996	Tompkins et al.	6,125,482	A	10/2000	Foster
5,551,637	A	9/1996	Lo	6,132,085	A	10/2000	Bergeron
5,555,912	A	9/1996	Saadi et al.	6,167,845	B1	1/2001	Decker, Sr.
5,564,462	A	10/1996	Storch	6,175,689	B1	1/2001	Blanco, Jr.
5,566,702	A	10/1996	Philipp	6,182,683	B1	2/2001	Sisk
5,570,869	A	11/1996	Diaz et al.	6,192,192	B1	2/2001	Illy et al.
5,572,985	A	11/1996	Benham	6,195,588	B1	2/2001	Gauthier et al.
5,577,660	A	11/1996	Hansen	6,202,980	B1	3/2001	Vincent et al.
5,584,316	A	12/1996	Lund	6,220,297	B1	4/2001	Marty et al.
5,586,572	A	12/1996	Lund	6,227,235	B1	5/2001	Laing et al.
5,588,636	A	12/1996	Eichholz et al.	6,240,250	B1	5/2001	Blanco, Jr.
5,595,216	A	1/1997	Pilolla	6,250,558	B1	6/2001	Dogre Cuevas
5,595,342	A	1/1997	McNair et al.	6,250,601	B1	6/2001	Kolar et al.
5,603,344	A	2/1997	Hall	6,273,394	B1	8/2001	Vincent et al.
5,609,370	A	3/1997	Szabo et al.	6,283,139	B1	9/2001	Symonds et al.
5,610,589	A	3/1997	Evans et al.	6,286,764	B1	9/2001	Garvey et al.
5,622,203	A	4/1997	Givler et al.	6,288,707	B1	9/2001	Philipp
5,623,990	A	4/1997	Pirkle	6,290,139	B1	9/2001	Kolze
5,627,375	A	5/1997	Hsieh	6,294,786	B1	9/2001	Marcichow et al.
5,650,597	A	7/1997	Redmayne	6,315,208	B1	11/2001	Doyle
5,651,384	A	7/1997	Rudrich	6,317,717	B1	11/2001	Lindsey et al.
5,655,749	A	8/1997	Mauerhofer	6,321,785	B1	11/2001	Bergmann
5,682,032	A	10/1997	Philipp	6,337,635	B1	1/2002	Ericksen et al.
5,694,653	A	12/1997	Harald	6,340,032	B1	1/2002	Zosimadis
5,729,422	A	3/1998	Henke	6,341,389	B2	1/2002	Philipps-Liebich et al.
5,730,165	A	3/1998	Philipp	6,351,603	B2	2/2002	Waithe et al.
5,735,291	A	4/1998	Kaonohi	6,363,549	B2	4/2002	Humpert
5,743,511	A	4/1998	Eichholz et al.	6,373,265	B1	4/2002	Morimoto et al.
5,755,262	A	5/1998	Pilolla	6,377,009	B1	4/2002	Philipp
5,758,688	A	6/1998	Hamanaka et al.	6,381,770	B1	5/2002	Raisch
5,758,690	A	6/1998	Humpert et al.	6,389,226	B1	5/2002	Neale et al.
5,769,120	A	6/1998	Laverty et al.	6,438,770	B1	8/2002	Hed et al.
5,771,501	A	6/1998	Shaw	6,445,306	B1	9/2002	Trovato et al.
5,775,372	A	7/1998	Houlihan	6,446,875	B1	9/2002	Brooks et al.
5,784,531	A	7/1998	Mann et al.	6,452,514	B1	9/2002	Philipp
5,790,024	A	8/1998	Rippling et al.	RE37,888	E	10/2002	Cretu-Petra
5,812,059	A	9/1998	Shaw et al.	6,457,355	B1	10/2002	Philipp
5,813,655	A	9/1998	Pinchott et al.	6,466,036	B1	10/2002	Philipp
5,819,366	A	10/1998	Edin	6,473,917	B1	11/2002	Mateina
5,829,467	A	11/1998	Spicher	6,474,951	B2	11/2002	Stephan et al.
5,829,475	A	11/1998	Acker	6,513,787	B1	2/2003	Jeromson et al.
5,845,844	A	12/1998	Zosimodis	6,522,078	B1	2/2003	Okamoto et al.
5,855,356	A	1/1999	Fait	6,535,134	B2	3/2003	Lang et al.
5,857,717	A	1/1999	Caffrey	6,535,200	B2	3/2003	Philipp
5,868,311	A	2/1999	Cretu-Petra	6,536,464	B1	3/2003	Lum et al.
5,872,891	A	2/1999	Son	6,549,816	B2	4/2003	Gauthier et al.
5,893,387	A	4/1999	Paterson et al.	6,574,426	B1	6/2003	Blanco, Jr.
5,915,417	A	6/1999	Diaz et al.	6,588,377	B1	7/2003	Leary et al.
5,918,855	A	7/1999	Hamanaka et al.	6,588,453	B2	7/2003	Marty et al.
5,934,325	A	8/1999	Brattoli et al.	6,612,267	B1	9/2003	West
5,941,275	A	8/1999	Laing	6,619,320	B2	9/2003	Parsons
5,941,504	A	8/1999	Toma et al.	6,622,930	B2	9/2003	Laing et al.
5,943,713	A	8/1999	Paterson et al.	6,629,645	B2	10/2003	Mountford et al.
5,944,221	A	8/1999	Laing et al.	6,639,209	B1	10/2003	Patterson et al.
				6,639,506	B1 *	10/2003	Landis G01F 1/684
							338/25
				6,644,333	B2	11/2003	Gloodt
				6,659,048	B1	12/2003	DeSantis et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

6,676,024 B1	1/2004	McNerney et al.	2003/0041374 A1	3/2003	Franke
6,684,822 B1	2/2004	Lieggi	2003/0080194 A1	5/2003	O'Hara et al.
6,691,338 B2	2/2004	Zieger	2003/0088338 A1	5/2003	Phillips et al.
6,705,534 B1	3/2004	Mueller	2003/0089399 A1	5/2003	Acker
6,707,030 B1	3/2004	Watson	2003/0125842 A1	7/2003	Chang et al.
6,734,685 B2	5/2004	Rudrich	2003/0126993 A1	7/2003	Lassota et al.
6,738,996 B1	5/2004	Malek et al.	2003/0185548 A1	10/2003	Novotny et al.
6,757,921 B2	7/2004	Esche	2003/0201018 A1	10/2003	Bush
6,768,103 B2	7/2004	Watson	2003/0213062 A1	11/2003	Honda et al.
6,770,869 B2	8/2004	Patterson et al.	2003/0234769 A1	12/2003	Cross et al.
6,779,552 B1	8/2004	Coffman	2004/0011399 A1	1/2004	Segien, Jr.
6,838,887 B2	1/2005	Denen et al.	2004/0041033 A1	3/2004	Kemp
6,845,526 B2	1/2005	Malek et al.	2004/0041034 A1	3/2004	Kemp
6,877,172 B2	4/2005	Malek et al.	2004/0041110 A1	3/2004	Kaneko
6,892,952 B2	5/2005	Chang et al.	2004/0061685 A1	4/2004	Ostergard et al.
6,895,985 B2	5/2005	Popper et al.	2004/0088786 A1	5/2004	Malek et al.
6,913,203 B2	7/2005	DeLangis	2004/0135010 A1	7/2004	Malek et al.
6,955,333 B2	10/2005	Patterson et al.	2004/0143898 A1	7/2004	Jost et al.
6,956,498 B1	10/2005	Gauthier et al.	2004/0144866 A1	7/2004	Nelson et al.
6,962,162 B2	11/2005	Acker	2004/0149643 A1	8/2004	Vandenbelt et al.
6,962,168 B2	11/2005	McDaniel et al.	2004/0155116 A1	8/2004	Wack et al.
6,964,404 B2	11/2005	Patterson et al.	2004/0206405 A1	10/2004	Smith et al.
6,964,405 B2	11/2005	Marcichow et al.	2004/0212599 A1	10/2004	Cok et al.
6,968,860 B1	11/2005	Haenlein et al.	2004/0262552 A1	12/2004	Lowe
6,993,607 B2	1/2006	Philipp	2005/0001046 A1	1/2005	Laing
6,995,670 B2	2/2006	Wadlow et al.	2005/0006402 A1	1/2005	Acker
6,998,545 B2	2/2006	Harkcom et al.	2005/0022871 A1	2/2005	Acker
7,006,078 B2	2/2006	Kim	2005/0044625 A1	3/2005	Kommers
7,014,166 B1	3/2006	Wang	2005/0086958 A1	4/2005	Walsh
7,015,704 B1	3/2006	Lang	2005/0117912 A1	6/2005	Patterson et al.
7,025,077 B2	4/2006	Vogel	2005/0121529 A1	6/2005	DeLangis
7,030,860 B1	4/2006	Hsu et al.	2005/0125083 A1	6/2005	Kiko
7,069,357 B2	6/2006	Marx et al.	2005/0127313 A1	6/2005	Watson
7,069,941 B2	7/2006	Parsons et al.	2005/0146513 A1	7/2005	Hill et al.
7,083,156 B2	8/2006	Jost et al.	2005/0150552 A1	7/2005	Forshey
7,096,517 B2	8/2006	Gubeli et al.	2005/0150556 A1	7/2005	Jonte
7,099,649 B2	8/2006	Patterson et al.	2005/0150557 A1	7/2005	McDaniel et al.
D528,991 S	9/2006	Katsuyama	2005/0151101 A1	7/2005	McDaniel et al.
7,102,366 B2	9/2006	Denen et al.	2005/0194399 A1	9/2005	Proctor
7,107,631 B2	9/2006	Lang et al.	2005/0199841 A1	9/2005	O'Maley
7,150,293 B2	12/2006	Jonte	2005/0199843 A1	9/2005	Jost et al.
7,174,577 B2	2/2007	Jost et al.	2005/0205818 A1	9/2005	Bayley et al.
7,174,579 B1	2/2007	Bauza	2005/0253102 A1	11/2005	Boilen et al.
7,228,874 B2	6/2007	Bolderheij et al.	2005/0273218 A1	12/2005	Breed et al.
7,232,111 B2	6/2007	McDaniels et al.	2006/0066991 A1	3/2006	Hirano et al.
7,278,624 B2	10/2007	Iott et al.	2006/0101575 A1	5/2006	Louis
7,307,485 B1	12/2007	Snyder et al.	2006/0130907 A1	6/2006	Marty et al.
7,537,023 B2	5/2009	Marty et al.	2006/0130908 A1	6/2006	Marty et al.
7,537,195 B2	5/2009	McDaniels et al.	2006/0138246 A1	6/2006	Stowe et al.
7,625,667 B2	12/2009	Marty et al.	2006/0145111 A1	7/2006	Lang et al.
7,690,395 B2	4/2010	Jonte et al.	2006/0153165 A1	7/2006	Beachy
7,766,026 B2	8/2010	Boey	2006/0186215 A1	8/2006	Logan
7,784,481 B2	8/2010	Kunkel	2006/0200903 A1	9/2006	Rodenbeck et al.
7,997,301 B2	8/2011	Marty et al.	2006/0201558 A1	9/2006	Marty et al.
8,104,113 B2	1/2012	Rodenbeck et al.	2006/0202142 A1	9/2006	Marty et al.
8,127,782 B2	3/2012	Jonte et al.	2006/0207019 A1	9/2006	Vincent
8,528,579 B2	9/2013	Jonte et al.	2006/0212016 A1	9/2006	Lavon et al.
8,561,626 B2	10/2013	Sawaski et al.	2006/0214016 A1	9/2006	Erdely et al.
8,613,419 B2	12/2013	Rodenbeck et al.	2006/0231638 A1	10/2006	Belz et al.
8,844,564 B2	9/2014	Jonte et al.	2006/0231782 A1	10/2006	Iott et al.
8,944,105 B2*	2/2015	Rodenbeck	2006/0231788 A1	10/2006	Cheng
	 E03C 1/057	2006/0237674 A1	10/2006	Iott et al.
		137/801	2006/0283511 A1	12/2006	Nelson
8,973,612 B2	3/2015	Sawaski et al.	2007/0001018 A1	1/2007	Schmitt et al.
2001/0011389 A1	8/2001	Philipps-Liebich et al.	2007/0057215 A1	3/2007	Parsons et al.
2001/0011390 A1	8/2001	Humpert et al.	2007/0069168 A1	3/2007	Jonte
2001/0011558 A1	8/2001	Schumacher	2007/0069169 A1	3/2007	Lin
2001/0011560 A1	8/2001	Pawelzik et al.	2007/0114073 A1	5/2007	Akel et al.
2001/0022352 A1	9/2001	Rudrich	2007/0138421 A1	6/2007	Gibson et al.
2002/0007510 A1	1/2002	Mann	2007/0156260 A1	7/2007	Rodenbeck et al.
2002/0015024 A1	2/2002	Westerman et al.	2007/0157978 A1	7/2007	Jonte
2002/0113134 A1	8/2002	Laing et al.	2007/0187635 A1	8/2007	Jost
2002/0117122 A1	8/2002	Lindner	2007/0246267 A1	10/2007	Koottungal
2002/0148040 A1	10/2002	Mateina	2007/0246550 A1	10/2007	Rodenbeck et al.
2002/0175789 A1	11/2002	Pimouguet	2007/0246564 A1	10/2007	Rodenbeck et al.
2002/0179723 A1	12/2002	Wack et al.	2008/0078019 A1	4/2008	Allen et al.
			2008/0099088 A1	5/2008	Boey
			2008/0109956 A1	5/2008	Bayley et al.
			2008/0178950 A1	7/2008	Marty et al.

(56)

References Cited**U.S. PATENT DOCUMENTS**

2008/0271238	A1	11/2008	Reeder et al.
2008/0289098	A1	11/2008	Kunkel
2009/0039176	A1	2/2009	Davidson et al.
2009/0119832	A1	5/2009	Conroy
2009/0160659	A1	6/2009	Bailey
2009/0293192	A1	12/2009	Pons
2010/0044604	A1	2/2010	Burke et al.
2010/0096017	A1	4/2010	Jonte et al.
2010/0108165	A1	5/2010	Rodenbeck et al.
2010/0170570	A1	7/2010	Rodenbeck et al.
2011/0253220	A1	10/2011	Sawaski et al.
2012/0055557	A1	3/2012	Belz et al.
2012/0318364	A1	12/2012	Sawaski et al.
2013/0186196	A1	7/2013	Veros et al.
2013/0276911	A1	10/2013	Meehan et al.

FOREIGN PATENT DOCUMENTS

DE	04401637	5/1998
DE	19815324	11/2000
EP	0961067 B1	12/1999
EP	1 134 895	9/2001
JP	63111383	5/1998
JP	200073426	3/2000
JP	2003-20703 A	1/2003
JP	2003105817	4/2003
JP	2003293411	10/2003
JP	2004-92023	3/2004
JP	2005-146551 A	6/2005
KR	10-1997-0700266	1/1997
KR	2003-0077823	10/2003
KR	20-0382786 Y1	4/2005
WO	WO 91/17377	11/1991
WO	WO 96 14477	5/1996
WO	WO 01/20204	3/2001
WO	WO 2004/094990	11/2004
WO	WO 2005/057086	6/2005
WO	WO 2006/098795	9/2006
WO	WO 2006/136256	12/2006
WO	WO 2007/059051	5/2007
WO	WO 2007/124311	11/2007
WO	WO 2007/124438	11/2007
WO	WO 2008/088534	7/2008
WO	WO 2008/094247	8/2008
WO	WO 2008/094651	8/2008
WO	WO 2008/118402	10/2008
WO	WO 2009/075858	6/2009

OTHER PUBLICATIONS

Dallmer Manutronic brochure, "The First Electronic mixer-taps that your hands can orchestrate," Dallmer Handel GmbH, at least as early as Jan. 31, 2008, 12 pgs.

Hego WaterDesign, "Touch Faucets-Amazing Futuristic Faucet Designs," Oct. 6, 2009, 3 pgs.

International Search Report and Written Opinion for PCT/US2007/025336, 5 pages, Sep. 2008.

International Search Report and Written Opinion for PCT/US2007/67116, 9 pages, Aug. 2008.

KWC AG, Kitchen Faucet 802285 Installation and Service Instructions, dated Jul. 2005, 8 pgs.

Philipp, Hal, "Tough Touch Screen," applianceDESIGN, Feb. 2006.

Quantum Research Group, "E401 User Manual," 15 pgs., Oct. 2007.

Quantum Research Group, "Gorenje Puts QSlide™ Technology into Next-Generation Kitchen Hob," Feb. 8, 2006, <http://www.qprox.com/news/gorenje.php>, 3 pgs.

Quantum Research Group, "Qprox™ Capacitive Touch Applications," <http://www.qprox.com/background/applications.php>, 8 pgs., at least prior to Jan. 2006.

Quantum Research Group, "QT401 QSlide™ Touch Slider IC," 2004, 16 pgs.

Quantum Research Group, "QT411-ISSG QSlide™ Touch Slider IC," 2004-2005, 12 pgs.

Sequine et al., Cypress Perform, "Application Notes AN2292," Oct. 31, 2005, 15 pgs.

Sequine et al., Cypress Perform, "Application Notes AN2233a," Apr. 14, 2005, 6 pgs.

Sloan® Optima® i.q. Electronic Hand Washing Faucet, Apr. 2004, 2 pgs.

Symmons, Ultra-Sense, Battery-Powered Faucets with PDS and Ultra-Sense AC Powered Faucets, © 1999-2004, 2 pgs.

Symmons, Ultra-Sense, Sensor Faucet with Position-Sensitive Detection, © 2001-2002, 2 pgs.

Symmons® Commercial Faucets: Reliability With a Sense of Style, 1 pg., Jan. 2006.

Symmons®, "Ultra-Sense® Battery-Powered, Sensor-Operated Lavatory Faucet S-6080 Series," Oct. 2002, 4 pgs.

Symmons®, "Ultra-Sense® Sensor Faucets with Position-Sensitive Detection," Aug. 2004, 4 pgs.

Technical Concepts International, Inc., Capri AutoFaucet® with Surround Sensor™ Technology, 500556, 500576, 500577, (at least as early as May 1, 2006), 1 pg.

Technical Concepts, AutoFaucet® with "Surround Sensor" Technology, Oct. 2005, 4 pgs.

TOTO® Products, "Self-Generating EcoPower System Sensor Faucet, Standard Spout," Specification Sheet, Nov. 2002, 2 pgs.

Various Products (available at least before Apr. 20, 2006), 5 pgs.

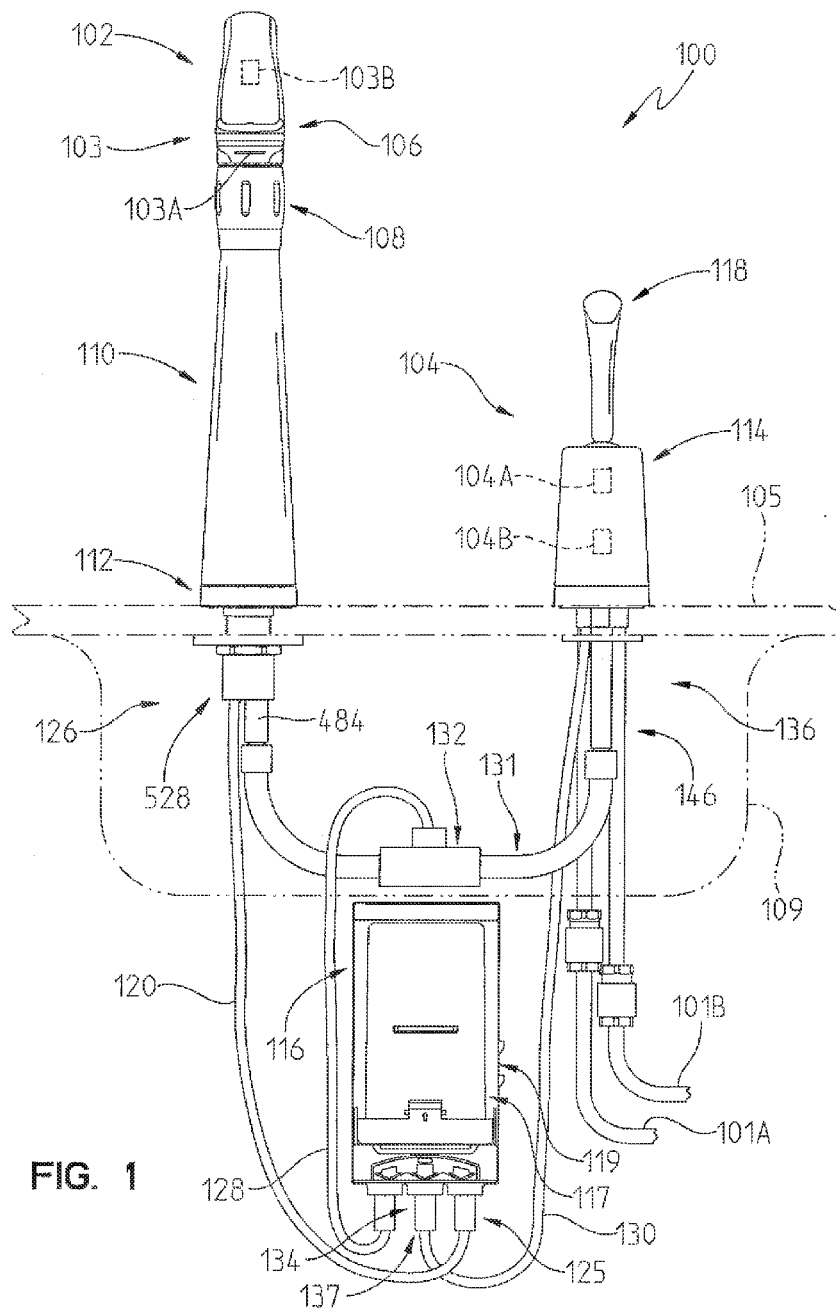
Villeroy & Boch "Magic Faucet," 2 pgs.

Villeroy & Boch web pages, "Magic Basin," 2 pgs., downloaded from <http://www.villeroy-boch.com> on Dec. 27, 2006.

Zurn® Plumbing Products Group, "AquaSense® Sensor Faucet," Jun. 9, 2004, 2 pgs.

Zurn® Plumbing Products Group, "AquaSense® Z6903 Series", Installation, Operation, Maintenance and Parts Manual, Aug. 2001, 5 pgs.

* cited by examiner



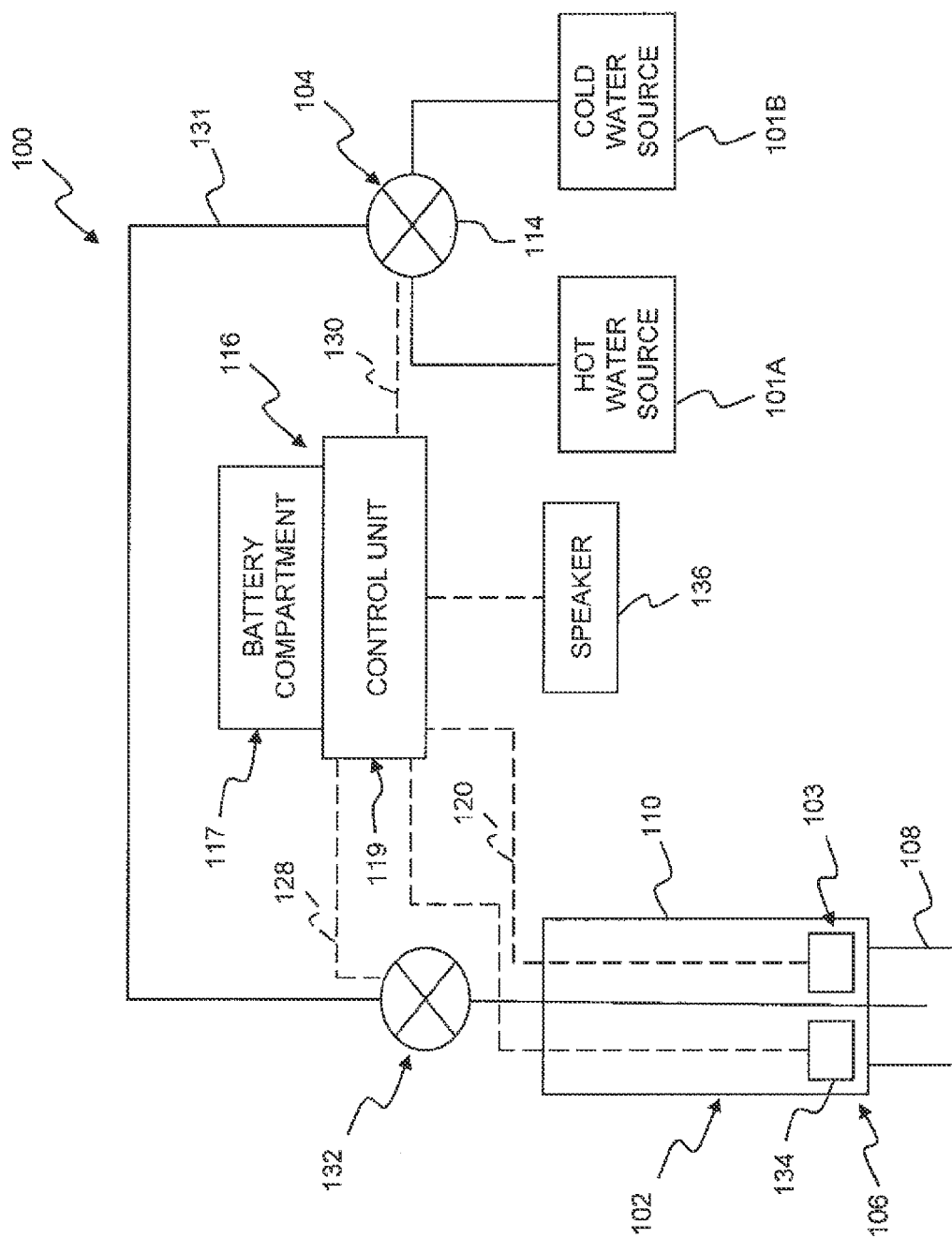
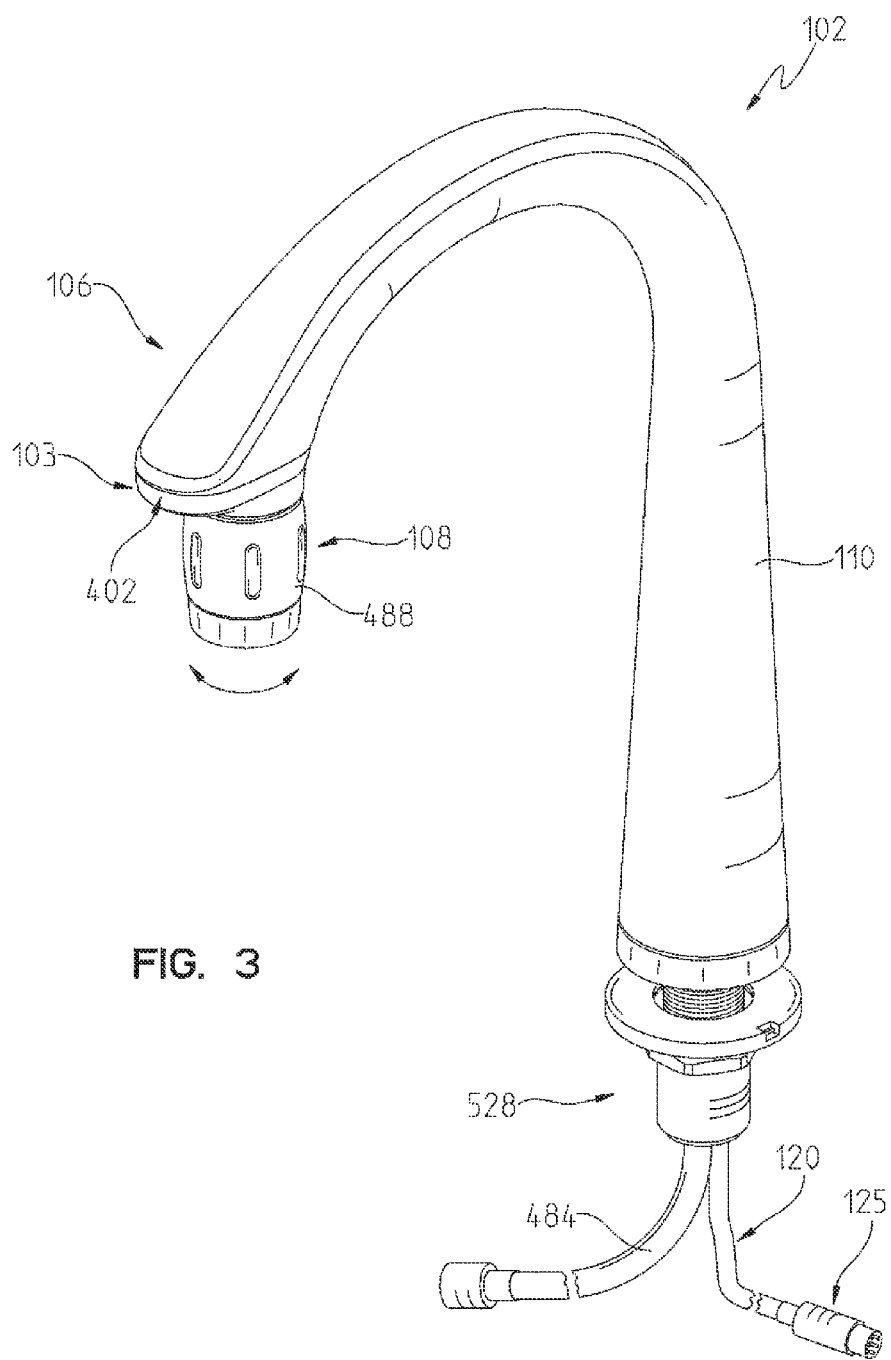
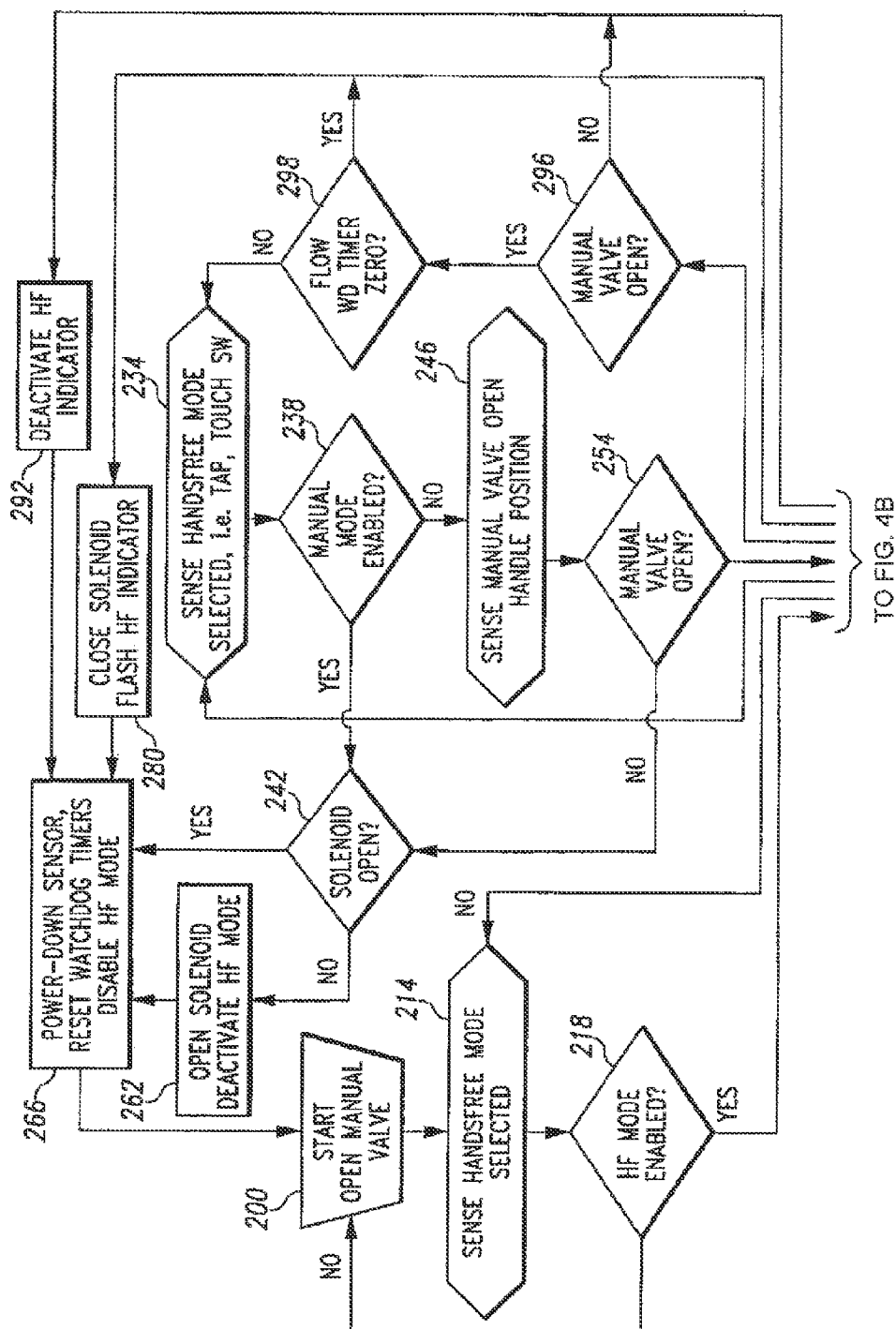


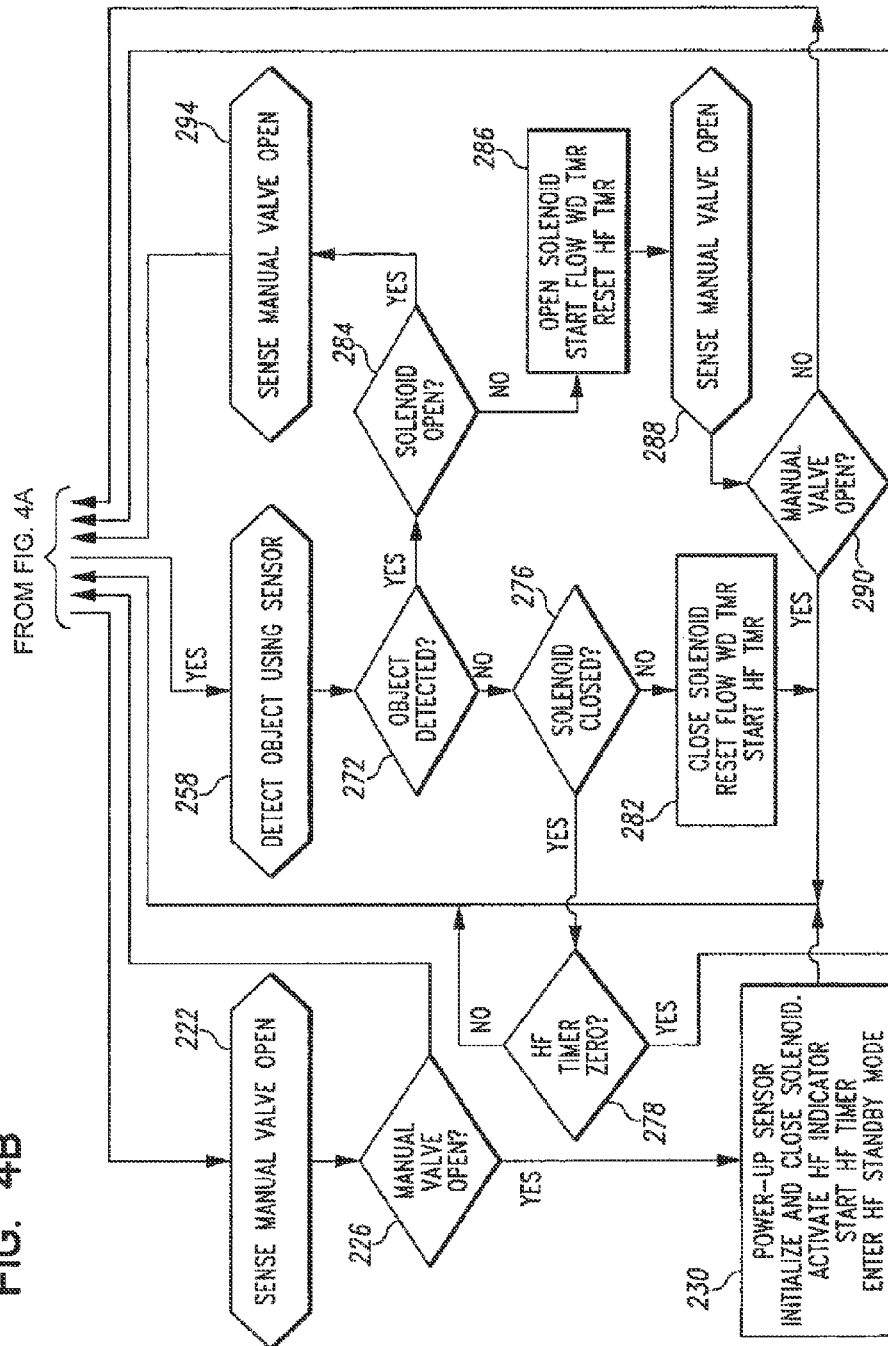
FIG. 2





4A

FIG. 4B



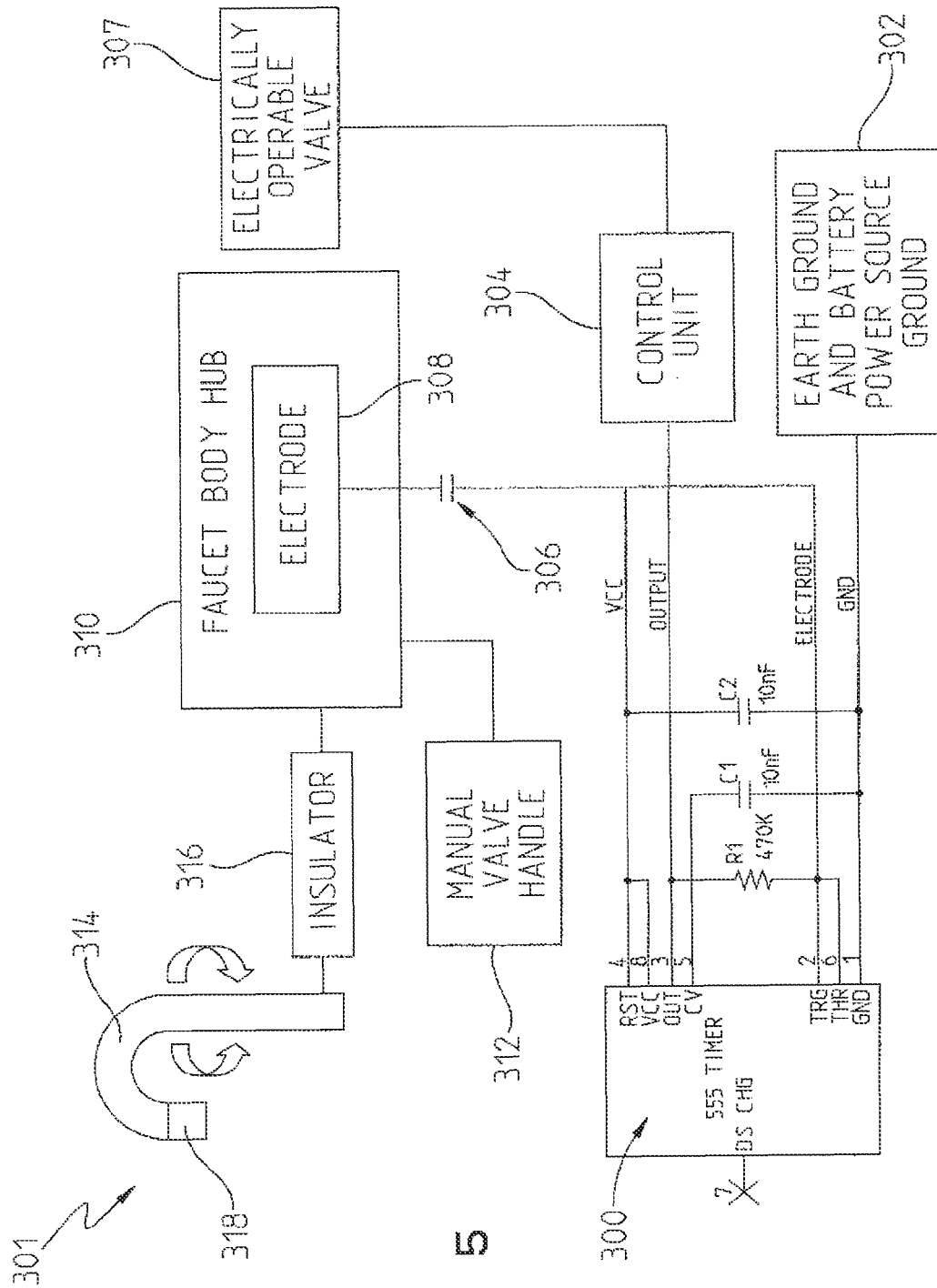


FIG. 5

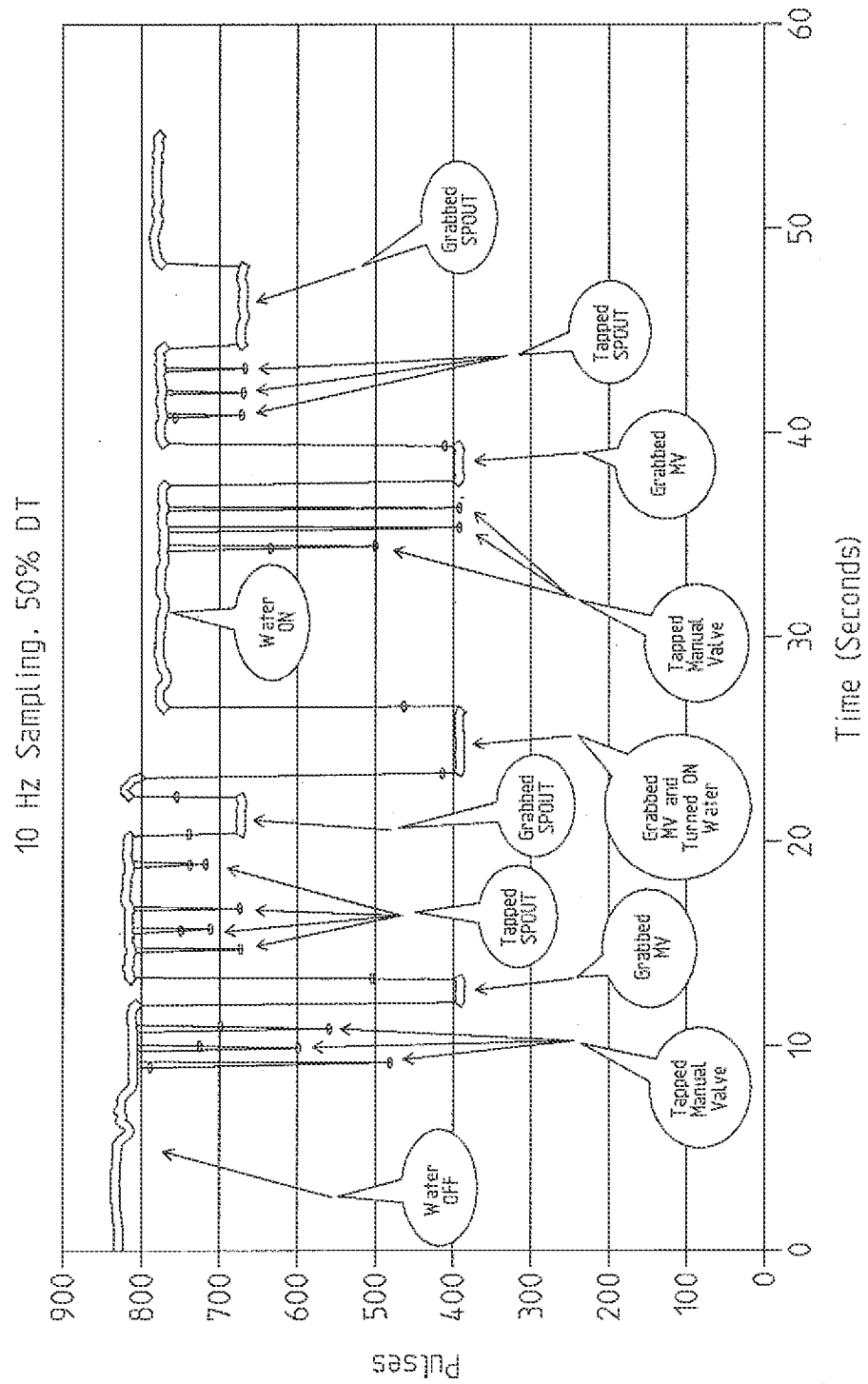
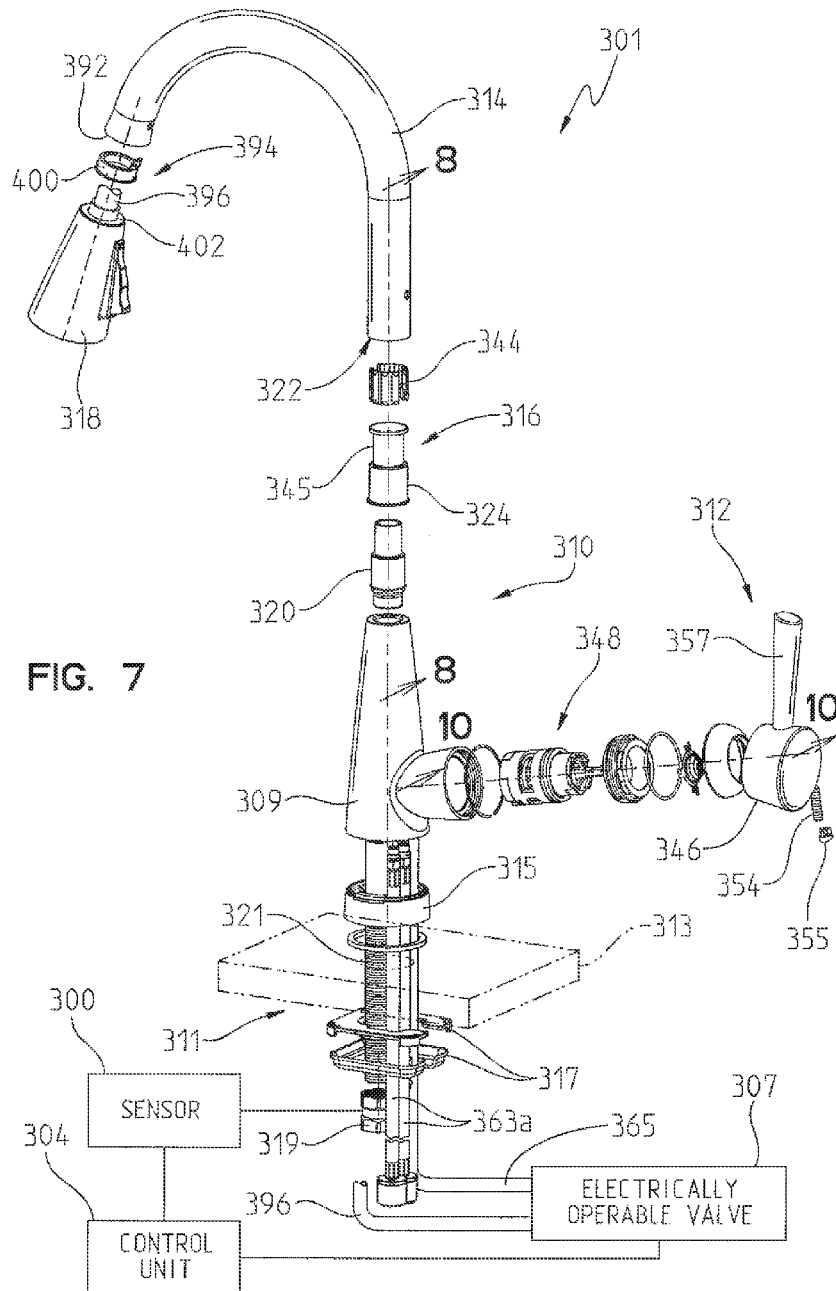


FIG. 6



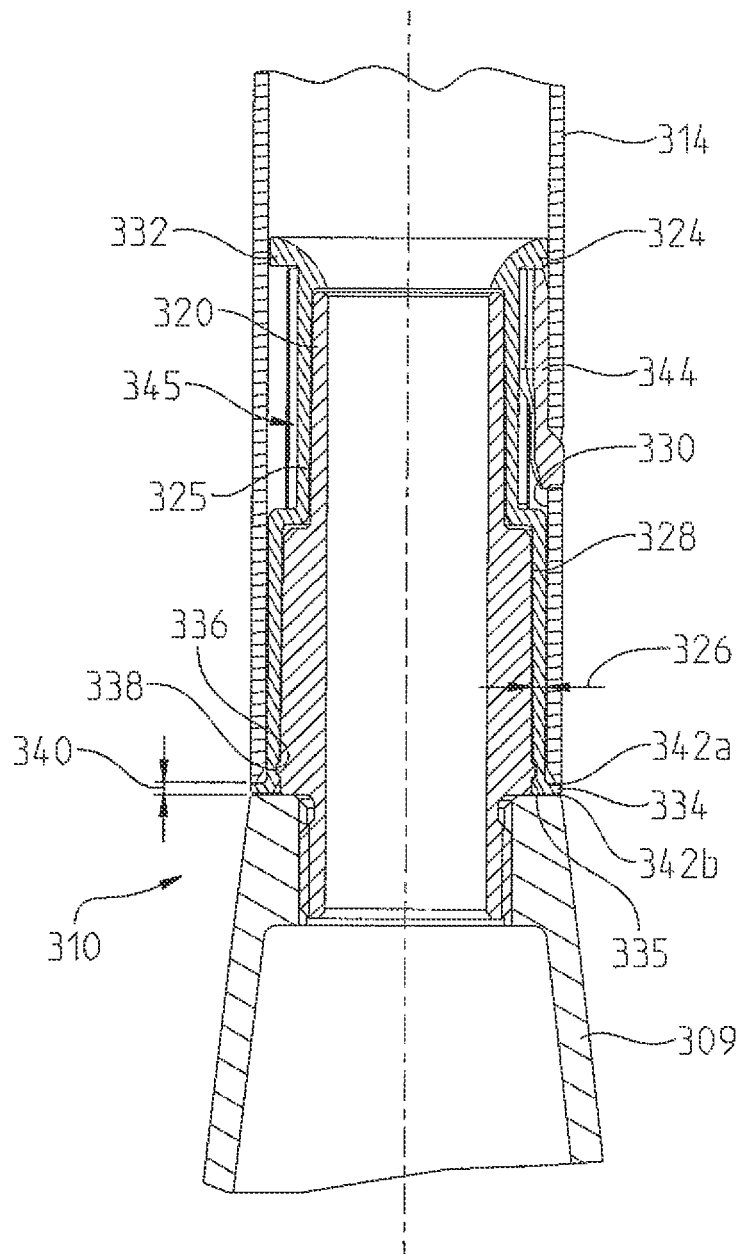
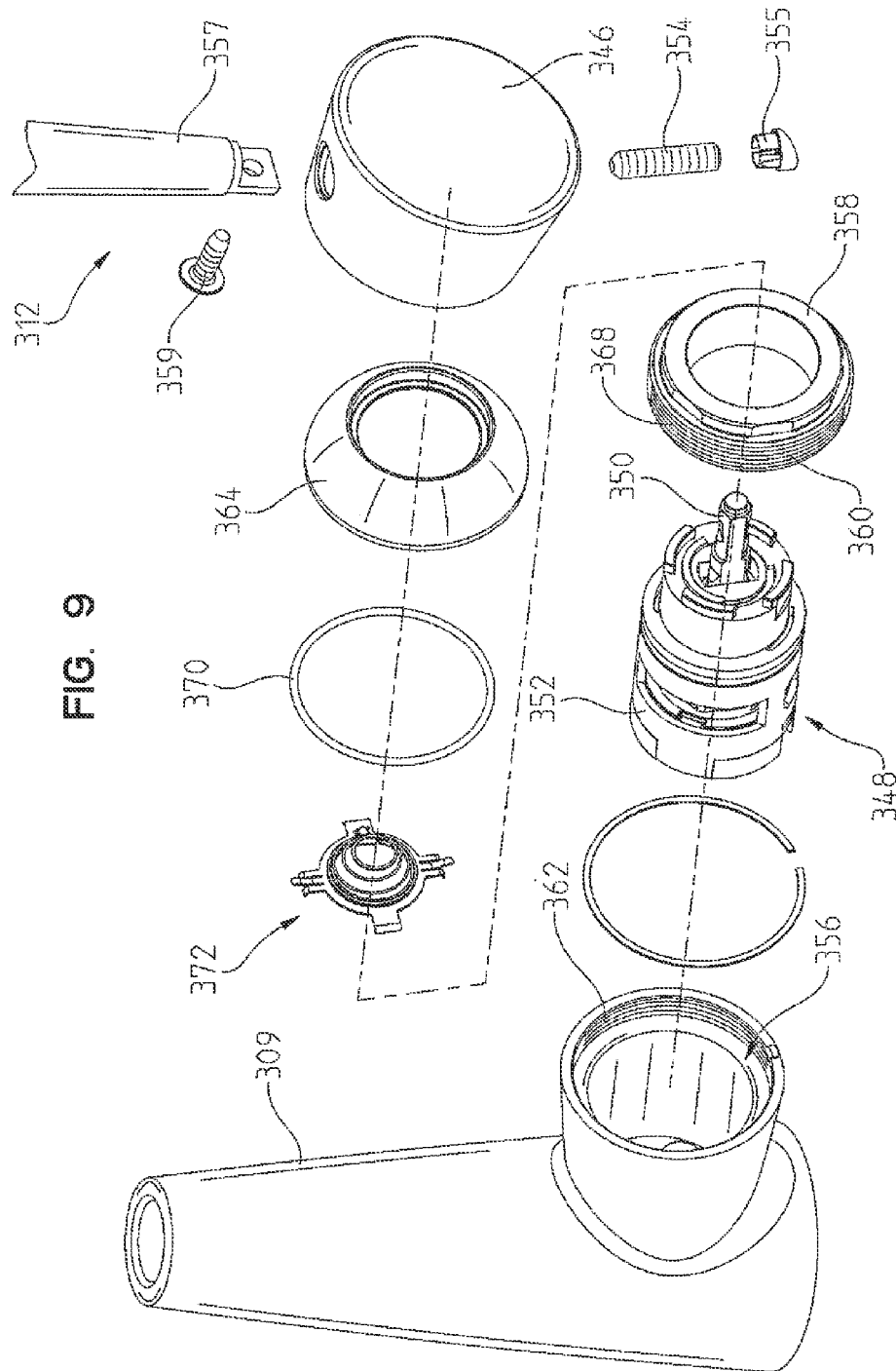


FIG. 8



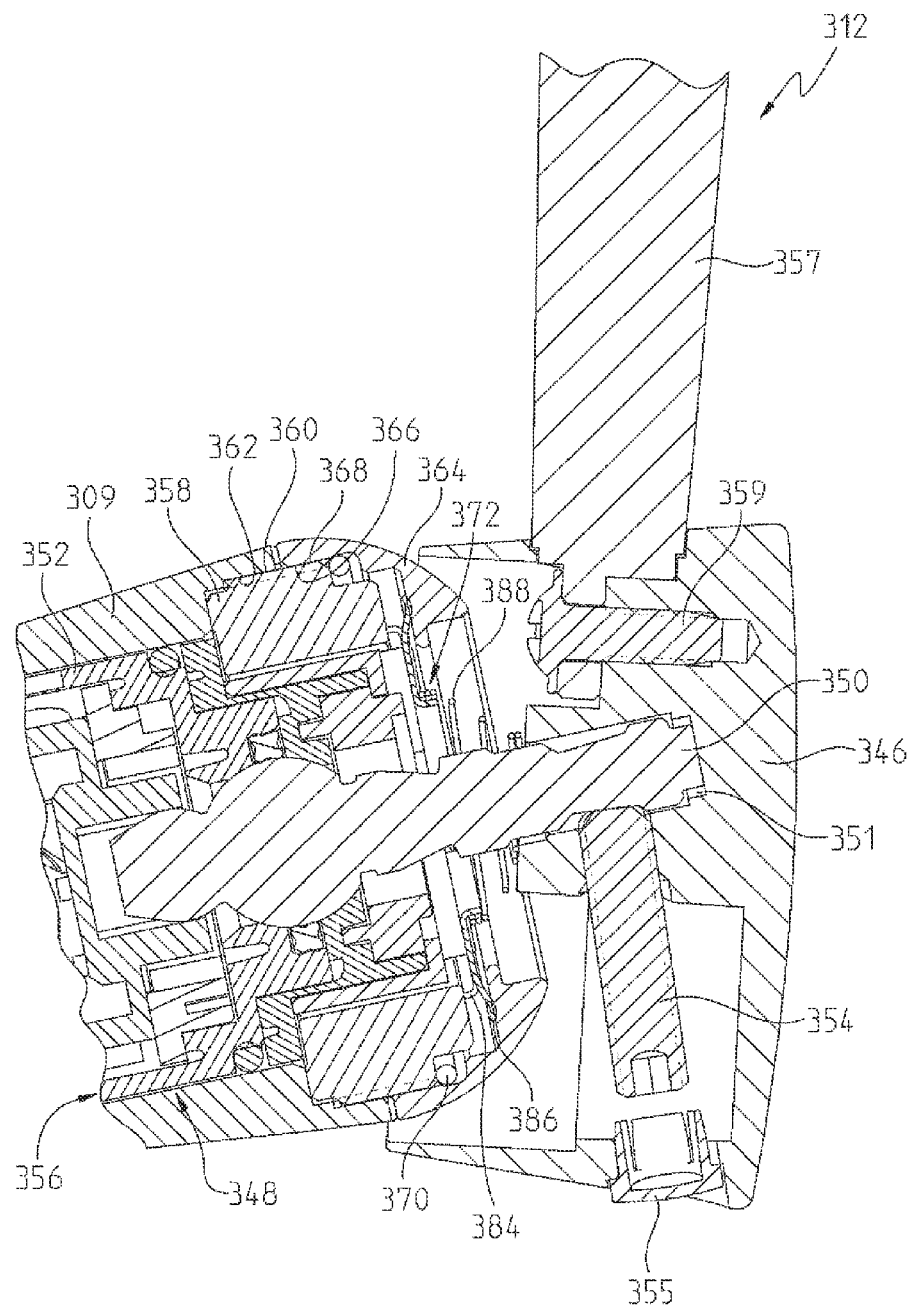


FIG. 10

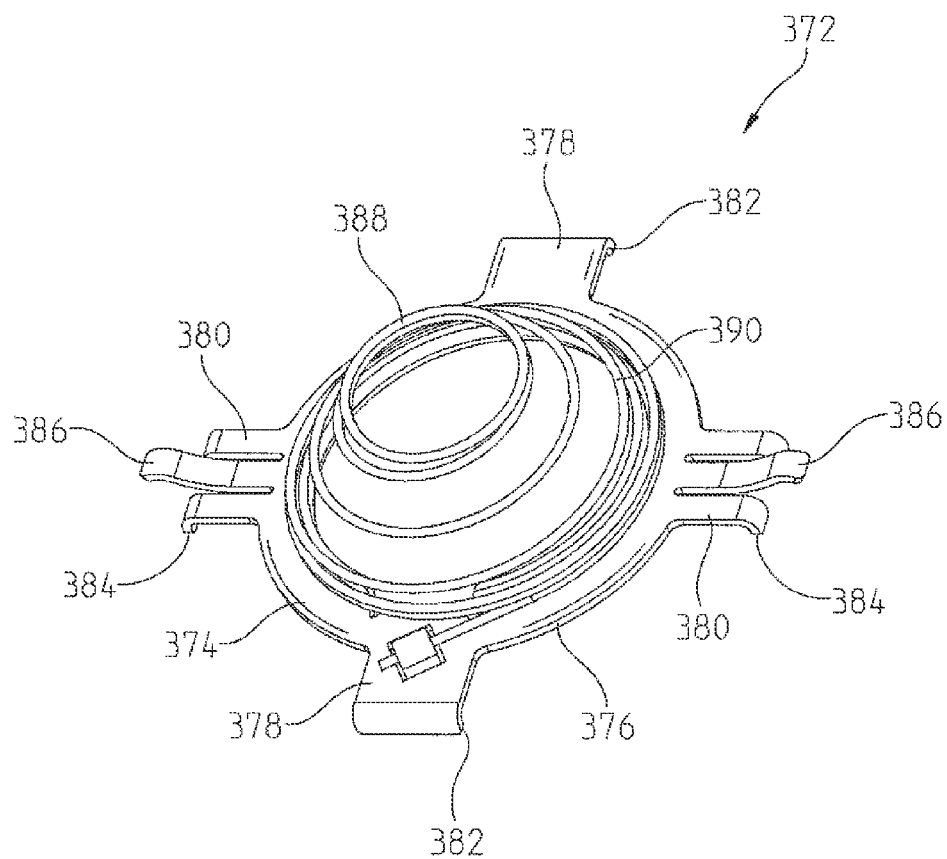


FIG. 11

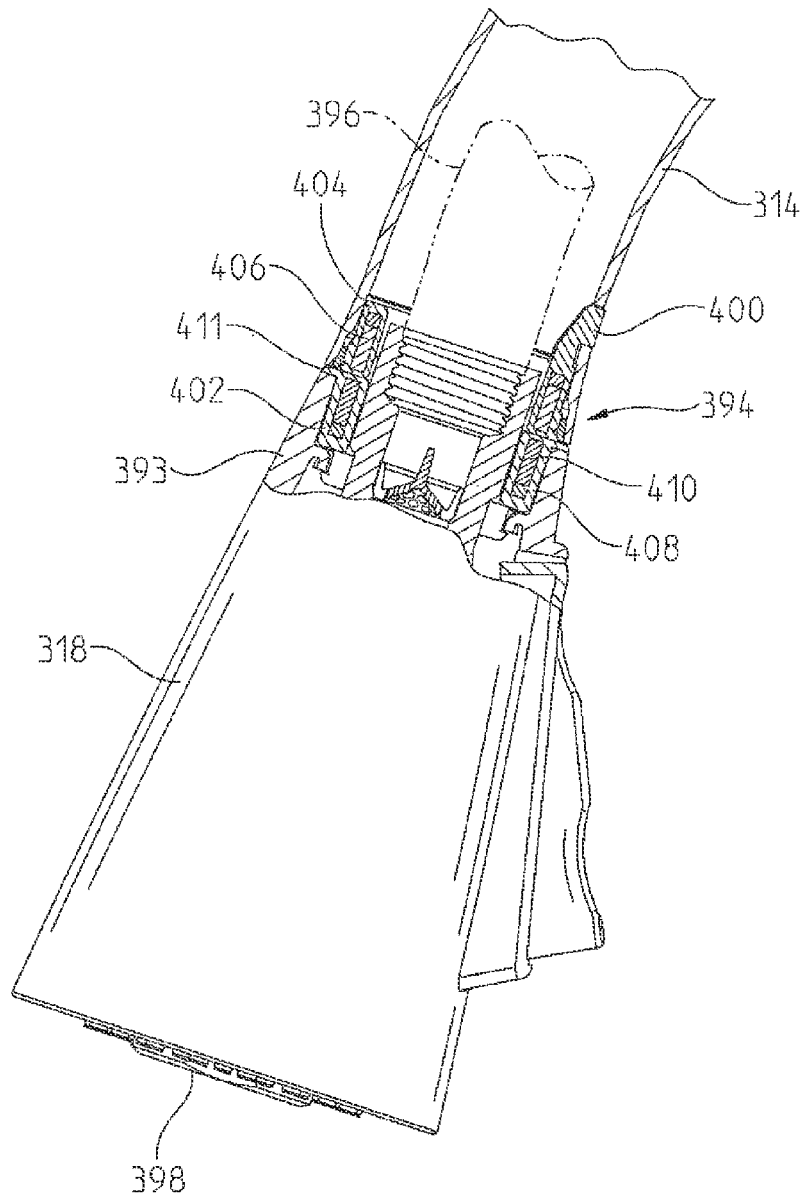
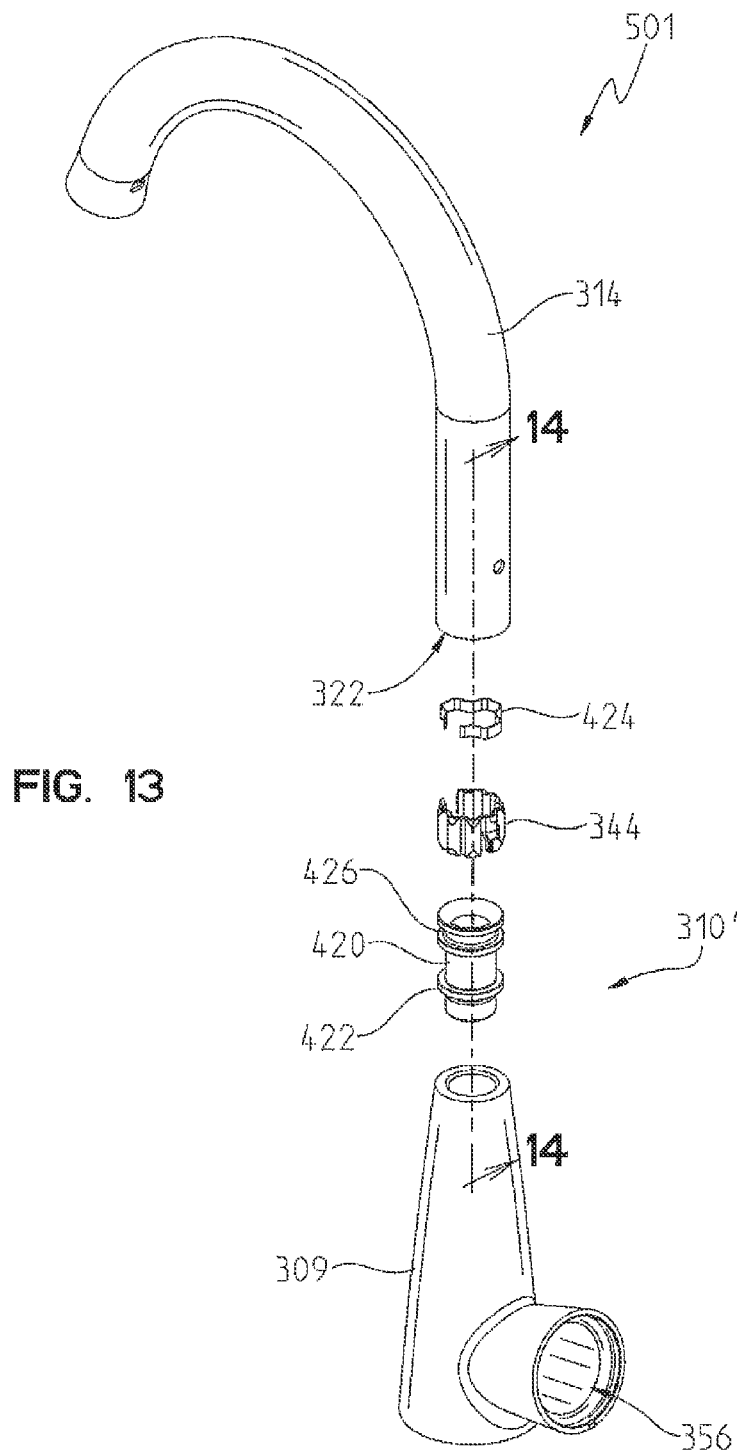


FIG. 12



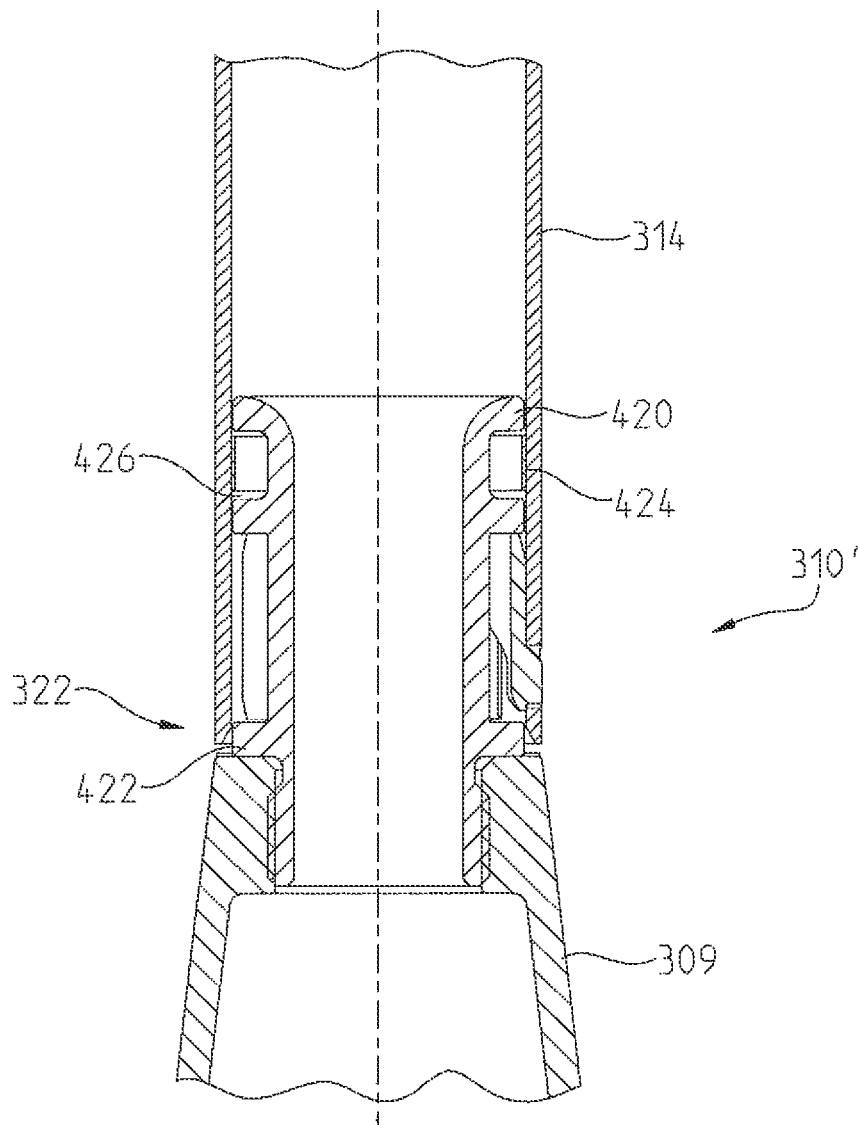


FIG. 14

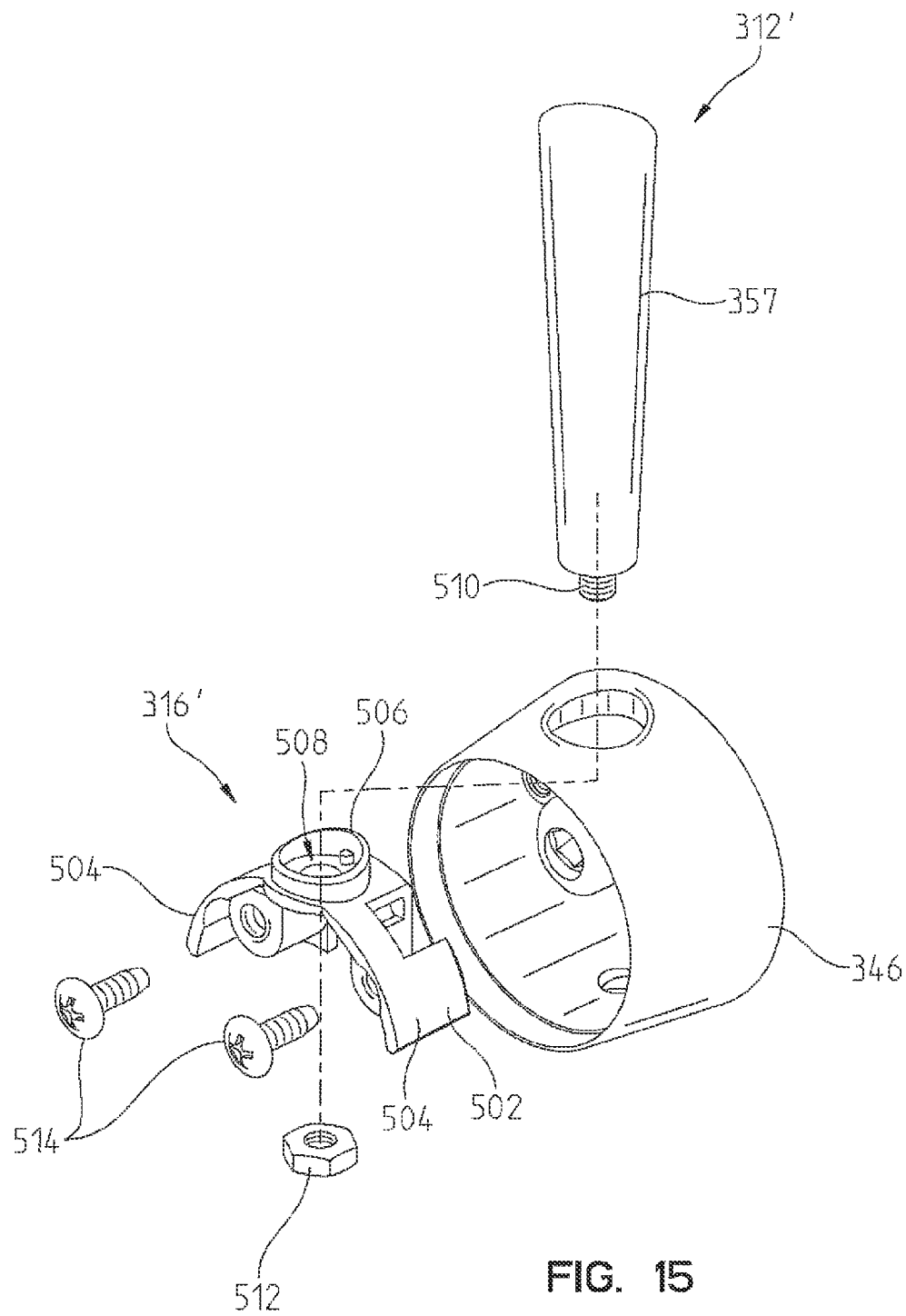


FIG. 15

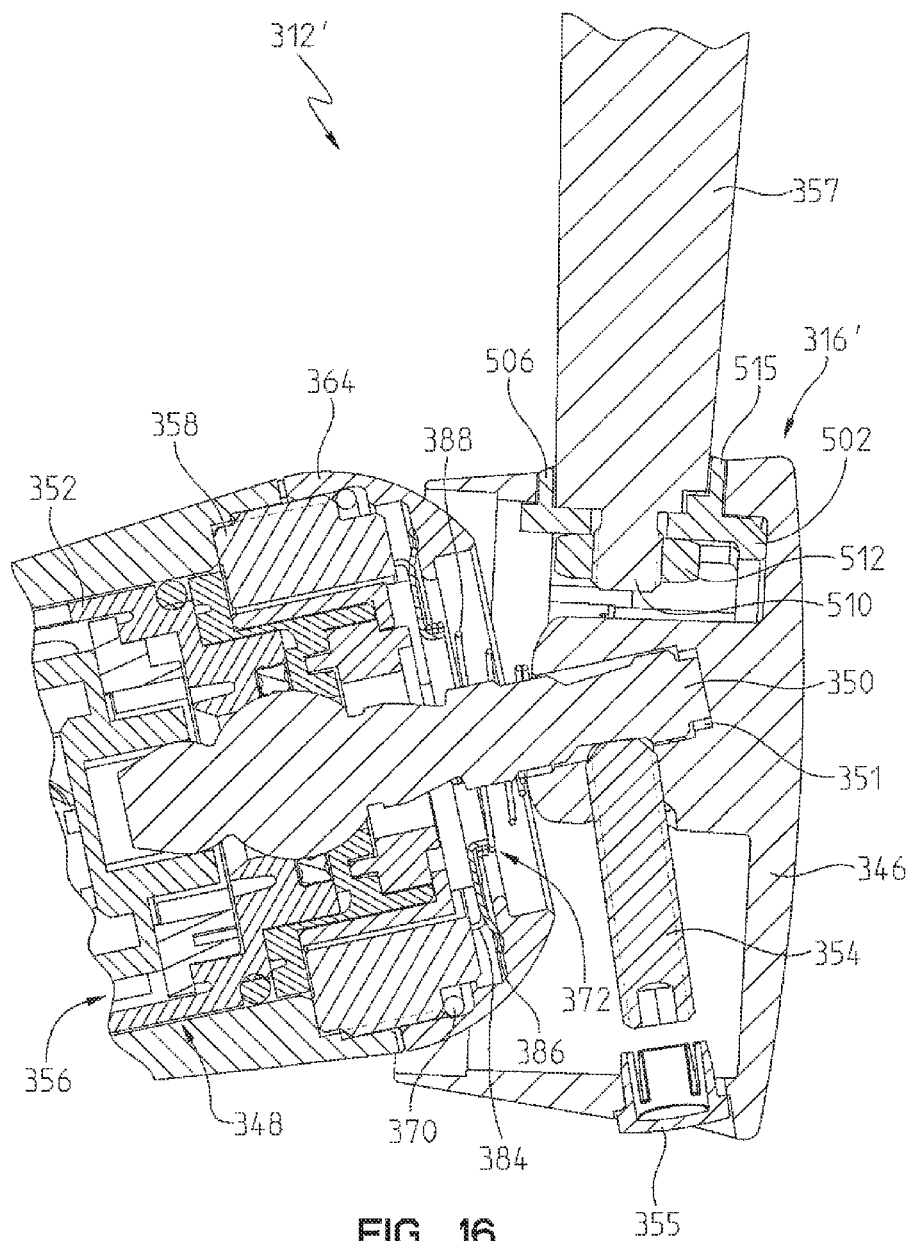


FIG. 16

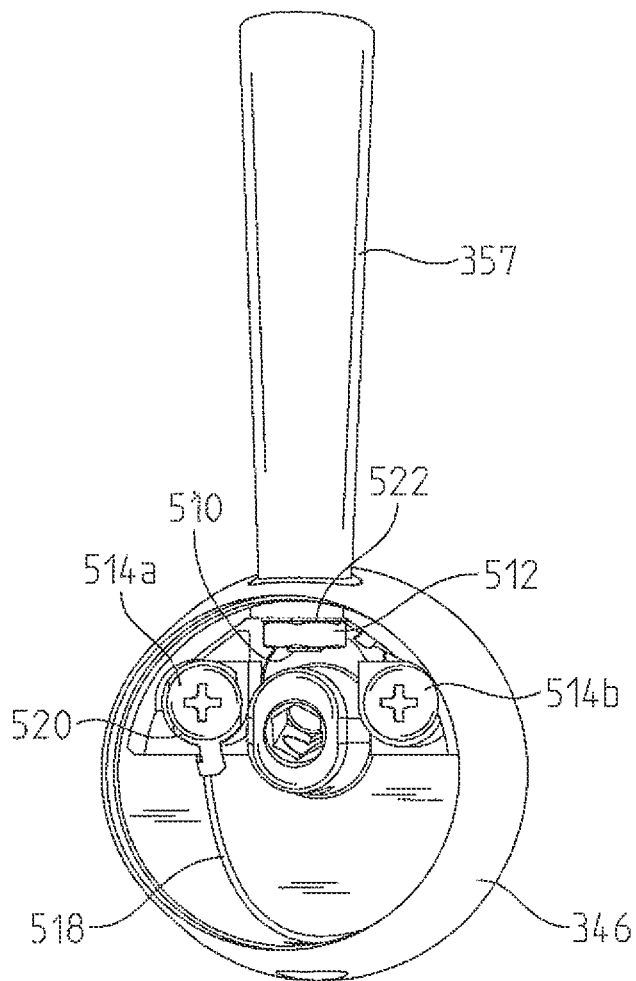
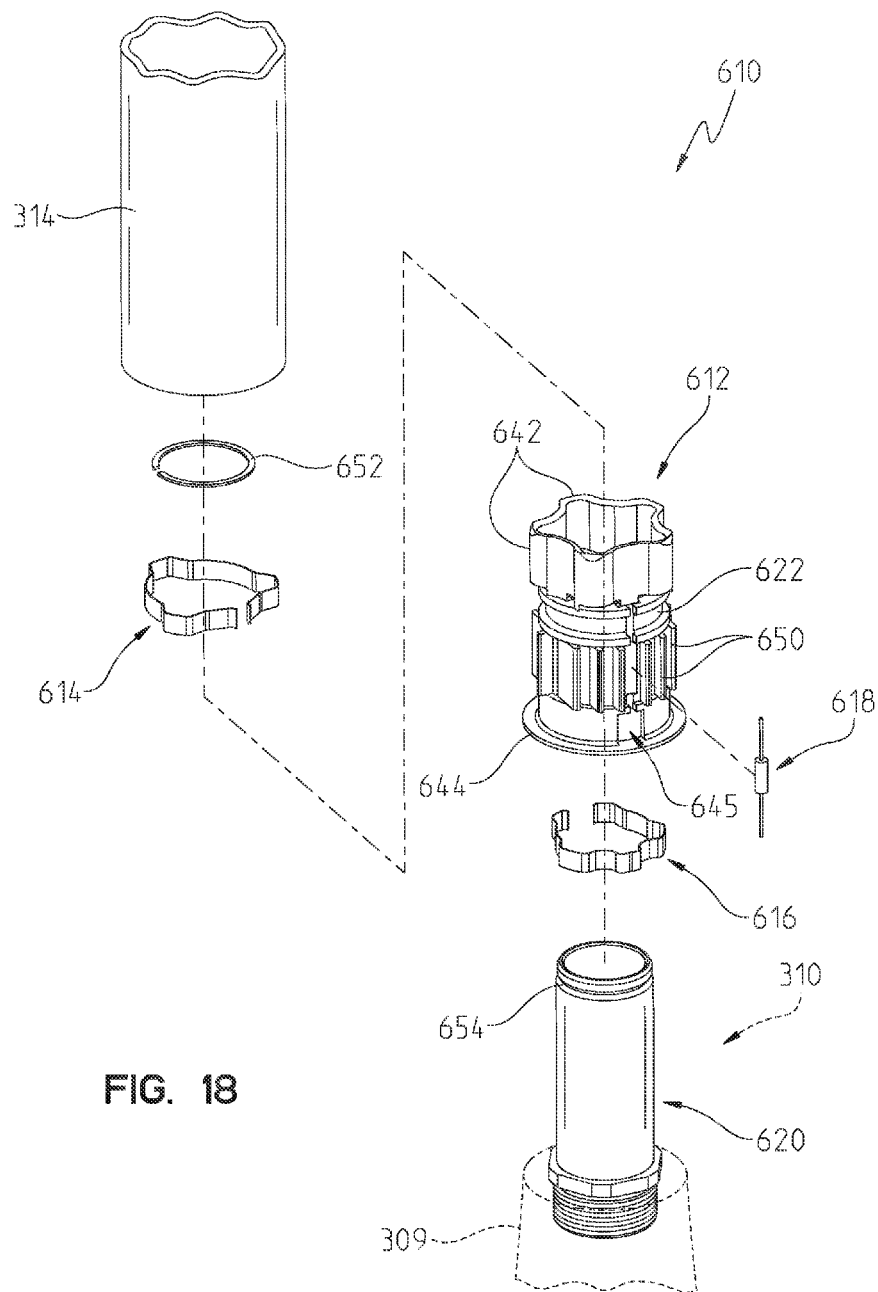


FIG. 17



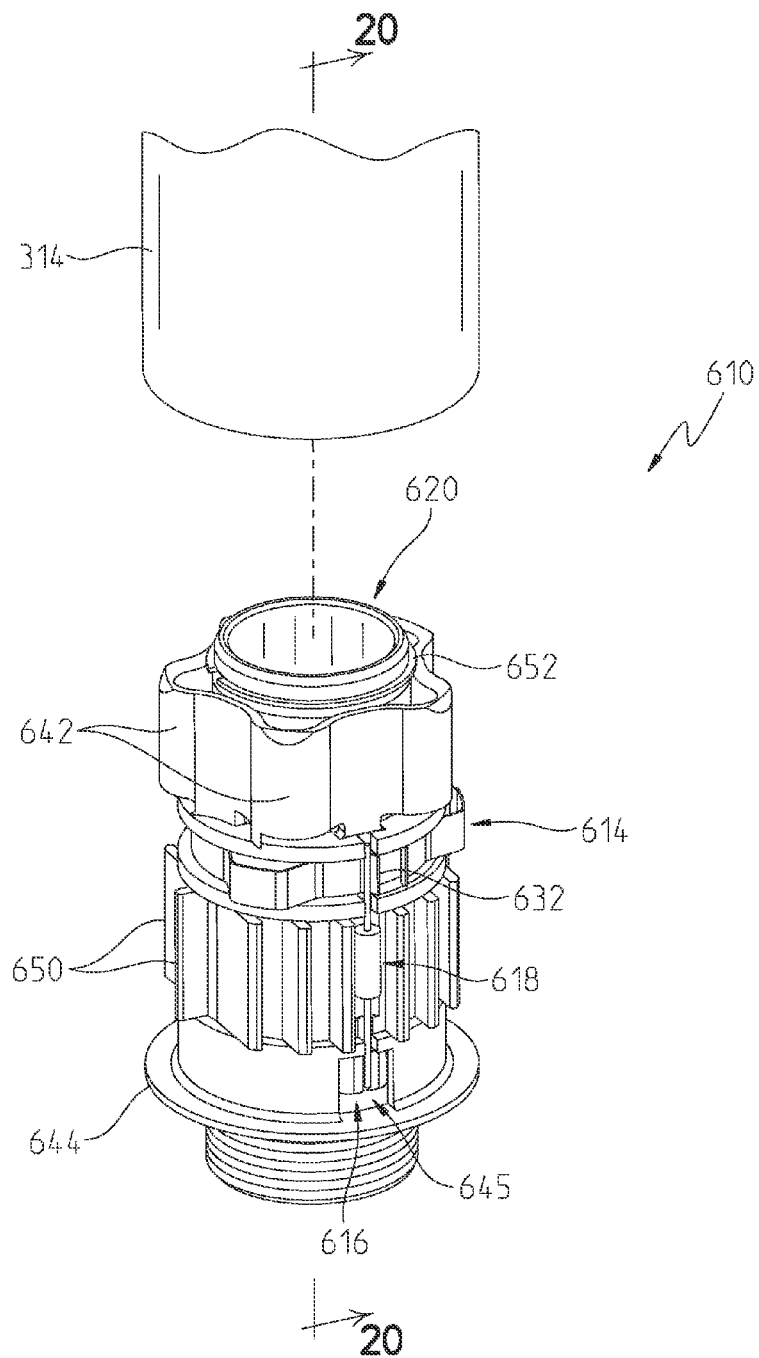


FIG. 19

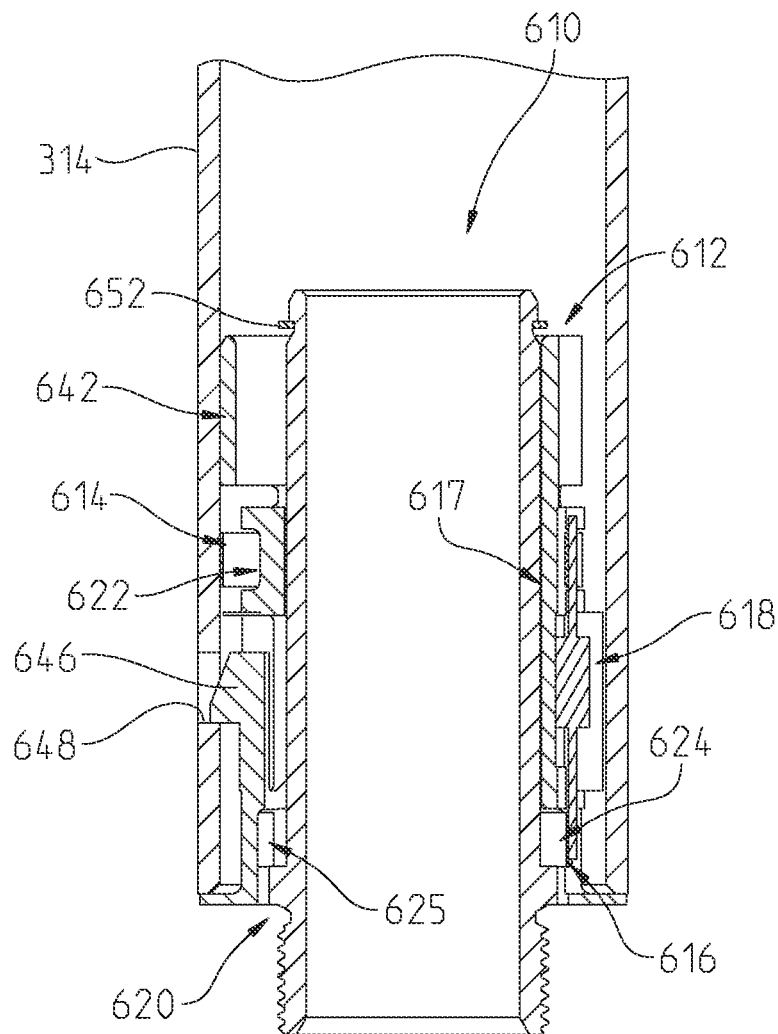


FIG. 20

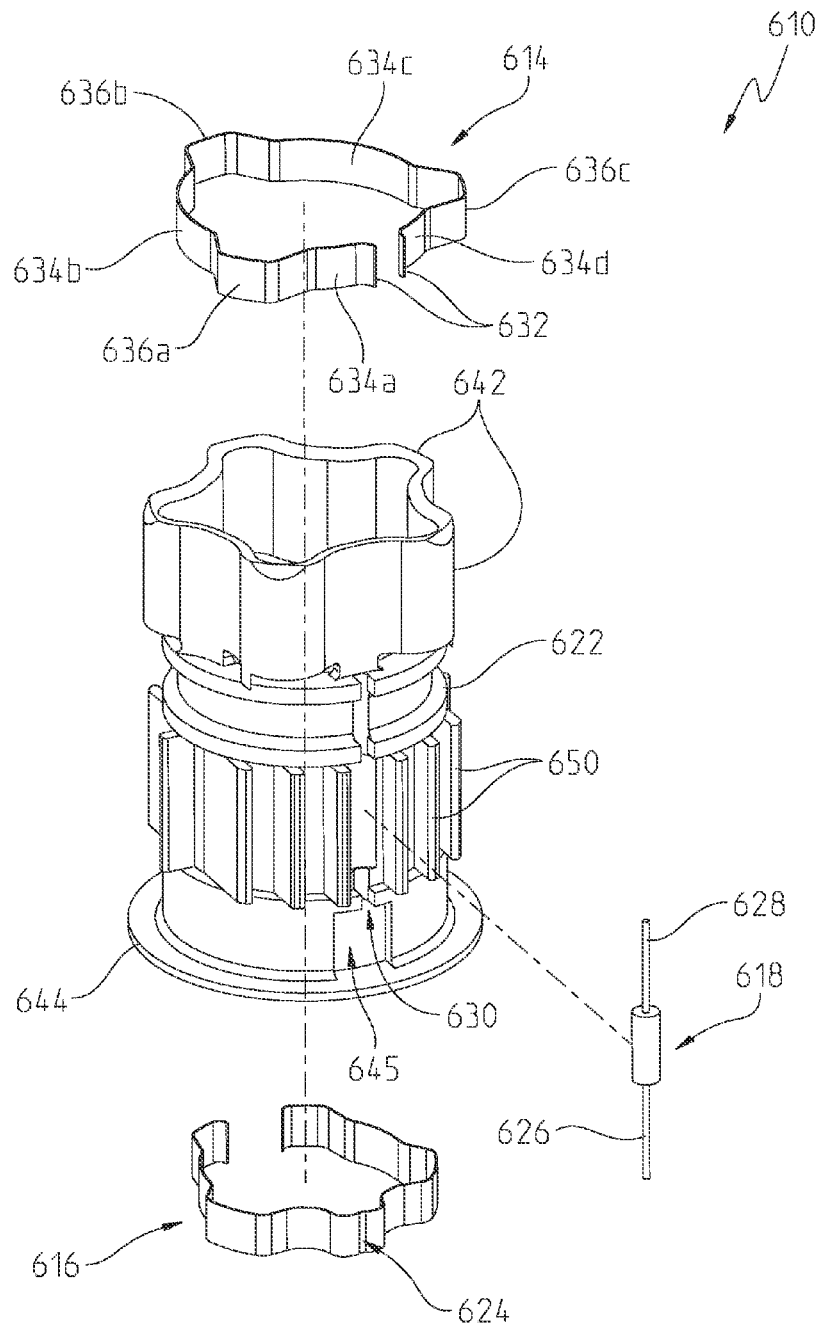


FIG. 21

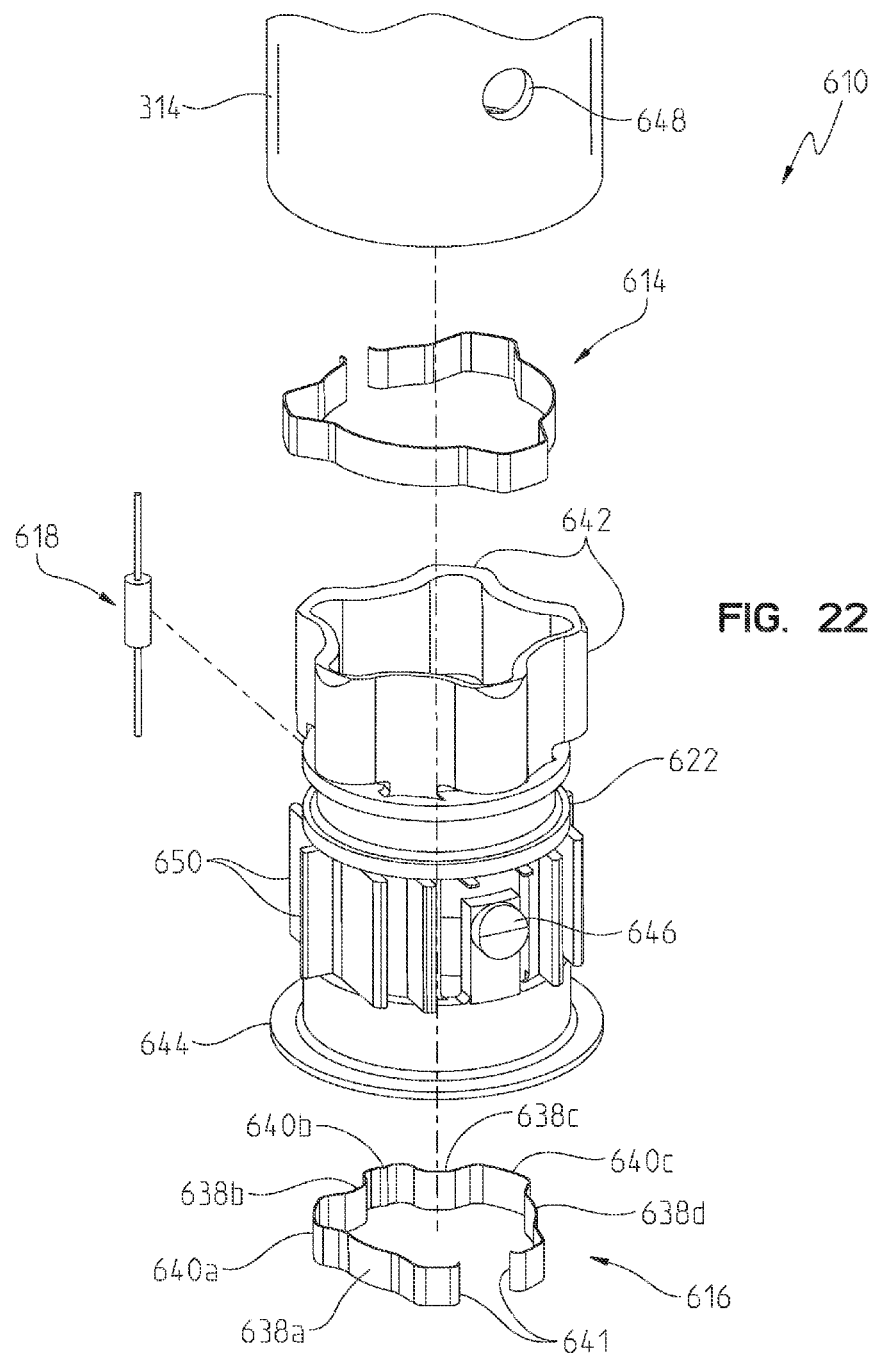
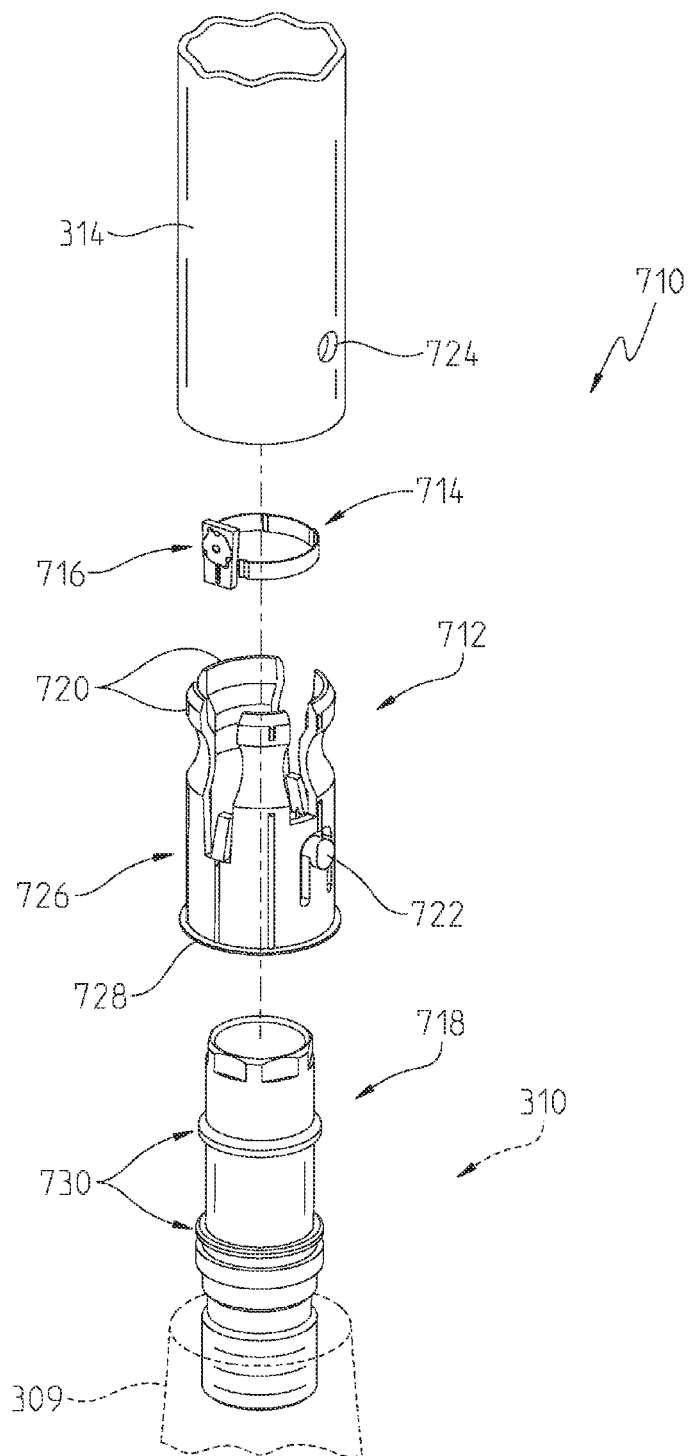


FIG. 23



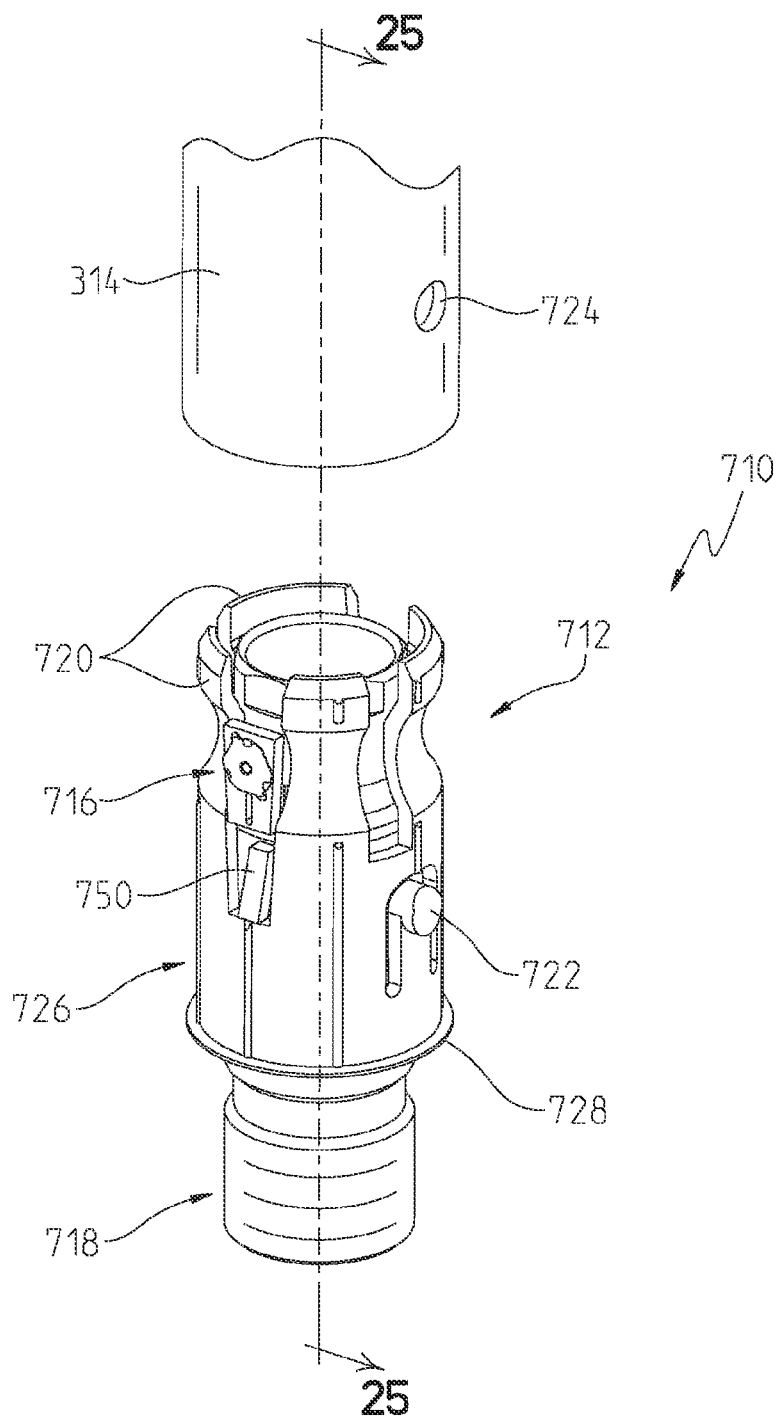
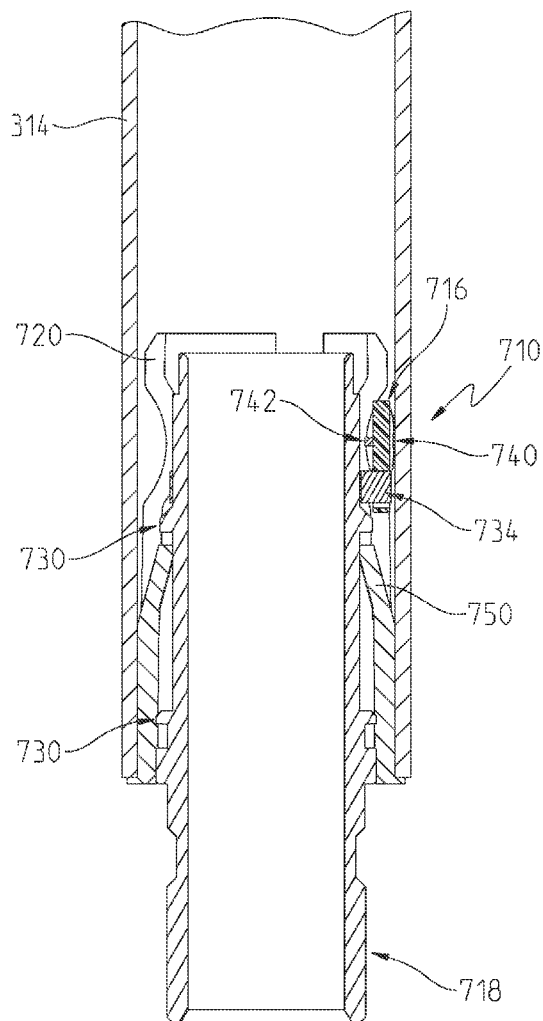


FIG. 24

FIG. 25



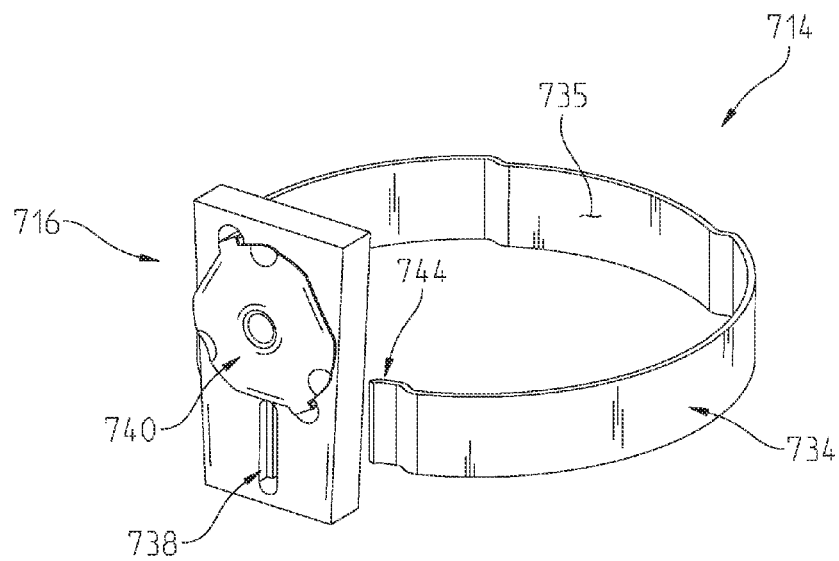


FIG. 26

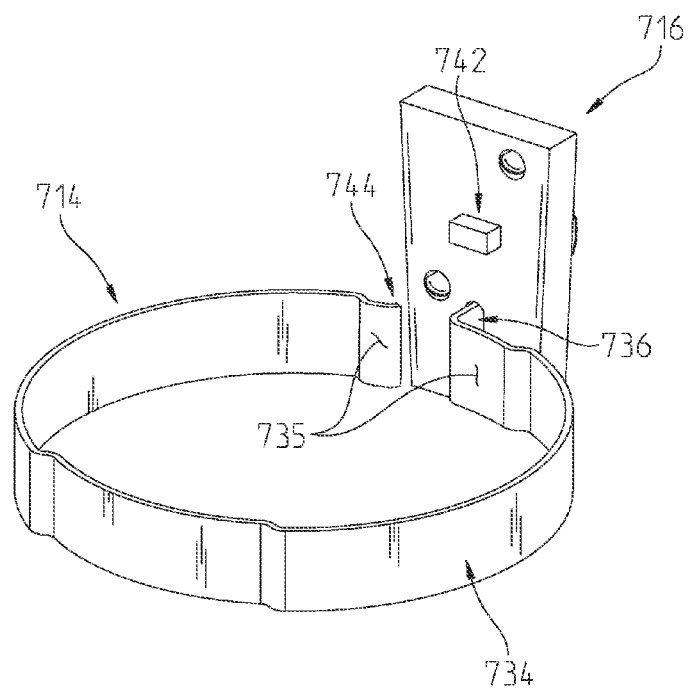


FIG. 27

1

RESISTIVE COUPLING FOR AN AUTOMATIC FAUCET

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 13/411,603, filed Mar. 4, 2012, now U.S. Pat. No. 8,844,564, which is a continuation of U.S. patent application Ser. No. 12/518,842, filed Jun. 11, 2009, now U.S. Pat. No. 8,127,782, which is a national phase filing of PCT International Application Ser. No. PCT/US2007/025336, filed Dec. 11, 2007, which is a continuation-in-part of U.S. patent application Ser. No. 11/641,574, filed Dec. 19, 2006, now U.S. Pat. No. 7,690,395, the disclosures of which are expressly incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to the field of automatic faucets. More particularly, the present invention relates to an automatic faucet that uses both proximity and contact sensors in conjunction with logic that responds to various actions to provide easy and intuitive operation.

2. Description of the Related Art

Automatic faucets have become popular for a variety of reasons. They save water, because water can be run only when needed. For example, with a conventional sink faucet, when a user washes their hands the user tends to turn on the water and let it run continuously, rather than turning the water on to wet their hands, turning it off to lather, then turning it back on to rinse. In public bathrooms the ability to shut off the water when the user has departed can both save water and help prevent vandalism.

One early version of an automatic faucet was simply a spring-controlled faucet, which returned to the "off" position either immediately, or shortly after, the handle was released. The former were unsatisfactory because a user could only wash one hand at a time, while the later proved to be mechanically unreliable.

A better solution was hands-free faucets. These faucets employ a proximity detector and an electric power source to activate water flow, and so can be operated without a handle. In addition to helping to conserve water and prevent vandalism, hands-free faucets also had additional advantages, some of which began to make them popular in homes, as well as public bathrooms. For example, there is no need to touch the faucet to activate it; with a conventional faucet, a user with dirty hands may need to wash the faucet after washing their hands. Non-contact operation is also more sanitary, especially in public facilities. Hands-free faucets also provide superior accessibility for the disabled, or for the elderly, or those who need assisted care.

Typically, these faucets use proximity detectors, such as active infrared ("IR") detectors in the form of photodiode pairs, to detect the user's hands (or other objects positioned in the sink for washing). Pulses of IR light are emitted by one diode with the other being used to detect reflections of the emitted light off an object in front of the faucet. Different designs use different locations on the spout for the photodiodes, including placing them at the head of the spout, farther down the spout near its base, or even at positions entirely separate from the spout. Likewise, different designs use different physical mechanisms for detecting the proximity of objects, such as ultrasonic signals or changes in the magnetic permeability near the faucet.

2

Examples of a hands-free faucets are given in U.S. Pat. No. 5,566,702 to Philippe, and U.S. Pat. No. 6,273,394 to Vincent, and U.S. Pat. No. 6,363,549 to Humpert, which are hereby incorporated herein in their entireties.

Although hands-free faucets have many advantages, depending on how they are used, some tasks may best be accomplished with direct control over the starting and stopping of the flow of water. For example, if the user wishes to fill the basin with water to wash something the hands-free faucet could be frustrating, since it would require the user to keep their hand continuously in the detection zone of the sensors. This is especially likely with a kitchen sink faucet, which may be used in many different tasks, such as washing dishes and utensils. Due to its size, the kitchen sink is often the preferred sink for filling buckets, pots, etc. Thus, there is a need for a kitchen faucet that provides water savings, but which does not interfere with other tasks in which a continuous flow is desired.

Each of these control methods has advantages for a particular intended task. Thus, what is needed is a faucet that provides both conventional, touch control, and hands-free operation modes, so that a user can employ the control mode that is best suited to the task at hand. The present invention is directed towards meeting this need, among others.

SUMMARY OF THE INVENTION

In an illustrative embodiment, the present invention provides a hands-free faucet comprising a proximity sensor, a handle, and a logical control. The logical control comprises a manual mode, wherein the proximity sensor is inactive, and wherein positioning the handle toggles water flow on and off. This logical control also comprises a hands-free mode, wherein water flow is toggled on and off in response to the proximity sensor. The mode-controller toggles the faucet between the hands-free mode and the manual mode. The handle comprises a touch control, the touch control controlling activation of water flow through the faucet in response to contact of a user with the handle that is insufficient to change a position of the handle.

In a further illustrative embodiment, the present invention provides a hands-free faucet comprising a proximity sensor and a logical control. The logical control comprises a manual mode, wherein the proximity sensor is inactive, and water flow is toggled on and off by positioning the handle; a hands-free mode, wherein water flow is toggled on and off in response to the proximity sensor; and a handle. The handle comprises a first touch control that puts the faucet in the hands-free mode when touched by a user; a second touch control that toggles the faucet between the hands-free mode and the manual mode when touched by a user; and a mode indicator that displays which mode the faucet is presently in. The water flow has a temperature and flow rate that is determined by the position of the handle.

In another illustrative embodiment, the present invention provides a hands-free kitchen-type faucet.

In a further illustrative embodiment, the present invention provides a kitchen-type faucet having a touch control that controls activation of water flow through the faucet in response to contact of a user with a handle, where the contact is insufficient to change a position of the handle.

In yet another illustrative embodiment, the present invention provides a hands-free faucet comprising a manual valve; an electrically operable valve in series with the manual valve; and a logical control comprising a manual mode and a hands-free mode, the logical control causing the electrically operable valve to open and close. The faucet enters the manual

mode when the faucet detects that water is not flowing through the faucet and the electrically operable valve is open.

In a further illustrative embodiment, the present invention provides a faucet comprising a pull-down spout, wherein pulling out the pull-down spout activates water flow.

In another illustrative embodiment, a faucet includes a spout, a handle, and a touch control operably coupled to at least one of the spout and the handle. A proximity sensor is provided and includes an active and an inactive state. A logical control is operably coupled to the touch control and the proximity sensor. The logical control includes a first mode, wherein the proximity sensor is inactive, and a second mode, wherein the proximity sensor is active. A mode indicator is configured to provide a visual indication of at least one of the first mode and the second mode.

According to a further illustrative embodiment, a faucet includes a spout, a handle, and a touch control operably coupled to at least one of the spout and the handle. A proximity sensor is provided and includes an active state and an inactive state. A logical control is operably coupled to the touch control and the proximity sensor. The logical control includes a first mode, wherein the proximity sensor is inactive, and a second mode, wherein the proximity sensor is active. The logical control further includes a mode controller that changes the faucet between the first mode and the second mode and responds to substantially simultaneous touching of the spout and the handle.

In a further illustrative embodiment, a faucet includes a spout, a handle, a touch control operably coupled to at least one of the spout and the handle, and a proximity sensor having an active state and an inactive state. A logical control is operably coupled to the touch control and the proximity sensor. The logical control includes a first mode, wherein the proximity sensor is inactive, and a second mode wherein the proximity sensor is active. An audio device is configured to provide an audible indication of transition between the first mode and the second mode.

In another embodiment of the present invention, a capacitive sensor is provided for use with a single hole mount faucet. In single hole mount faucets, the spout and manual valve handle are coupled to a faucet body hub which is connected to a single mounting hole. The capacitive sensor may be either coupled to a new faucet or retrofit onto an existing faucet without impacting the industrial design or requiring redesign of the faucet.

In an illustrated embodiment, a capacitive sensor is electrically connected to the faucet body hub. The handle of the manual control valve is electrically coupled to the faucet body hub due to metal-to-metal contact between the handle and the hub. However, the spout is coupled to the faucet body hub with an insulator or impedance coupling. Therefore, the spout is capacitively coupled to the faucet body hub. A larger capacitance difference is detected when the handle is grasped by a user compared to when the spout is grasped. Therefore, a controller can determine where a user is touching the faucet (i.e., the handle or the spout), and for how long, in order to control operation of the faucet in different modes. In a further illustrative embodiment, the handle of the manual control valve is capacitively coupled to the hub through the use of an insulator.

In another illustrative embodiment, a faucet is provided including a first faucet component, a second faucet component, and a sensor coupled to at least one of the first faucet component and the second faucet component. The faucet further includes a resistor assembly coupled to the first faucet component and the second faucet component. The resistor assembly includes an insulating adapter, a first electrical con-

tact coupled to the insulating adapter and in contact with the first faucet component, a second electrical contact coupled to the insulating adapter and in contact with the second faucet component, and a resistor electrically coupled between the first electrical contact and the second electrical contact.

In yet another illustrative embodiment, a resistor assembly for a faucet is provided. The resistor assembly includes an insulating adapter having a cylindrical wall. The cylindrical wall forms an opening configured to receive a first faucet component of the faucet. The resistor assembly includes a first electrical contact and a second electrical contact. The first electrical contact is coupled to an inner surface of the insulating adapter and is configured to contact the first faucet component. The second electrical contact is coupled to the insulating adapter and is configured to contact a second faucet component of the faucet. The resistor assembly further includes a resistor mounted to the insulating adapter and electrically coupled between the first electrical contact and the second electrical contact.

Additional features and advantages of the present invention will become apparent to those skilled in the art upon consideration of the following detailed description of the illustrative embodiment exemplifying the best mode of carrying out the invention as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

Although the characteristic features of this invention will be particularly pointed out in the claims, the invention itself, and the manner in which it may be made and used, may be better understood by referring to the following description taken in connection with the accompanying figures forming a part hereof.

FIG. 1 is a front plan view of an illustrative embodiment electronic faucet system including a valve body assembly having an electrical cable extending therefrom to a controller assembly, and a spout assembly having an electrical cable extending therefrom to the controller assembly;

FIG. 2 is a block diagram illustrating the electronic faucet system of FIG. 1;

FIG. 3 is a top, front side perspective view of the spout assembly of FIG. 1;

FIGS. 4A and 4B are diagrams of a logical control for an illustrative embodiment faucet according to the present invention;

FIG. 5 is a block diagram with schematic portions illustrating another embodiment of the present invention which provides a capacitive sensor for use with a single hole mount faucet;

FIG. 6 is an illustrative output from the capacitive sensor of the embodiment of FIG. 5;

FIG. 7 is an exploded perspective view of an illustrative embodiment single hole mount faucet;

FIG. 8 is a partial cross-sectional view of the faucet of FIG. 7 taken along line 8-8;

FIG. 9 is a partial exploded perspective view of the faucet of FIG. 7;

FIG. 10 is a partial cross-sectional view of the handle coupling of the faucet of FIG. 7 taken along 10-10;

FIG. 11 is a perspective view of the contact assembly of FIG. 10;

FIG. 12 is a side view, in partial cross-section, of the spray head coupled to the spout of FIG. 7;

FIG. 13 is an exploded perspective view of a further illustrative embodiment spout coupling;

FIG. 14 is partial cross-sectional view of the spout coupling of FIG. 13 taken along lines 14-14;

5

FIG. 15 is a partial exploded perspective view of a handle coupling for use in combination with the spout coupling of FIG. 13;

FIG. 16 is a cross-sectional view of the handle coupling of FIG. 15;

FIG. 17 is a rear plan view of a further illustrative embodiment spout coupling;

FIG. 18 is an exploded perspective view of a resistor coupling according to an illustrative embodiment for coupling a spout to a hub;

FIG. 19 is a perspective view of the resistor coupling of FIG. 18;

FIG. 20 is a cross-sectional view of the resistor coupling taken along lines 20-20 of FIG. 19;

FIG. 21 is an exploded perspective view of the resistor coupling of FIG. 18;

FIG. 22 is another exploded perspective view of the resistor coupling of FIG. 18 shown from an opposite side as the view of FIG. 21;

FIG. 23 is an exploded perspective view of an alternative resistor coupling according to another illustrative embodiment for coupling a spout to a hub;

FIG. 24 is a perspective view of the resistor coupling of FIG. 23;

FIG. 25 is a cross-sectional view of the resistor coupling taken along lines 25-25 of FIG. 24;

FIG. 26 is a perspective view of a contact ring assembly of the resistor coupling of FIG. 23; and

FIG. 27 is another perspective view of the contact ring assembly of the resistor coupling of FIG. 23 shown from an opposite side as the view of FIG. 26.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the preferred embodiment and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Such alternations and further modifications in the invention, and such further applications of the principles of the invention as described herein as would normally occur to one skilled in the art to which the invention pertains, are contemplated, and desired to be protected.

An illustrative embodiment of the present invention provides a kitchen-type faucet that can be placed in at least two modes, in order to provide water-efficient operation that is easy and convenient to use. In a hands-free mode, the water is activated and deactivated in response to a proximity sensor that detects when something is presently under the spout, so as to provide the most water-efficient operation, while still maintaining easy and convenient operation and use. For other applications, such as filling the sink to wash dishes, or filling pots, bottles, or other such items, the faucet can be operated in manual mode, wherein the water is controlled by a manual handle as with a conventional faucet. When the faucet is manually closed and not in use, the faucet is returned to manual mode, and the proximity detector is deactivated, so that power consumption is limited, making it practical to power the faucet with batteries.

FIG. 1 is a perspective view of an illustrative embodiment kitchen-type faucet according to the present invention, indicated generally at 100. It will be appreciated that kitchen-type faucets and lavatory-type faucets are distinguished by a variety of features, such as the size of their spouts, the ability of the spout to swivel, and, often, the manual control. These

6

features are related to the different applications for which they are used. Kitchen-type faucets are generally used for longer periods, and for washing and filling a variety of objects, while lavatory-type faucets are used mostly to wash the user's hands and face. Kitchen-type faucets typically have longer and higher spouts, in order to facilitate placing objects, such as dishes, pots, buckets, etc., under them. Kitchen-type faucets typically rise at least 6 inches above the deck of the sink, and may rise more than a foot. In addition, kitchen-type faucets typically swivel in the horizontal plane, so that they can be directed into either of the pair of basins in a typical kitchen sink. Lavatory-type faucets, on the other hand, are usually fixed, since even bathrooms with more than one sink basin are typically fitted with a separate faucet for each. In addition, kitchen-type faucets are generally controlled by a single manual handle that controls both the hot and cold water supplies, because it makes it easier to operate while one hand is holding something. Lavatory-type faucets more often have separate hot and cold water handles, in part for aesthetic reasons. Although there are exceptions to each of these general rules, in practice kitchen-type faucets and lavatory-type faucets are easily distinguished by users.

While the present invention's multi-mode operation is especially useful for kitchen sinks, the present invention may also be used with a lavatory-type faucet.

An illustrative embodiment faucet according to the present invention comprises a manually controlled valve in series with an actuator driven valve, illustratively a magnetically latching pilot-controlled solenoid valve. Thus, when the solenoid valve is open the faucet can be operated in a conventional manner, in a manual control mode. Conversely, when the manually controlled valve is set to select a water temperature and flow rate the solenoid valve can be touch controlled, or activated by proximity sensors when an object (such as a user's hands) is within a detection zone to toggle water flow on and off. An advantageous configuration for a proximity detector and logical control for the faucet in response to the proximity detector is described in greater detail in U.S. patent application Ser. No. 10/755,582, filed Jan. 12, 2004, entitled "Control Arrangement for an Automatic Residential Faucet," which is hereby incorporated in its entirety.

It will be appreciated that a proximity sensor is any type of device that senses proximity of objects, including, for example, typical infrared or ultrasound sensors known in the art. Touch or contact sensors, in contrast, sense contact of objects.

Magnetically latching solenoids comprise at least one permanent magnet. When the armature is unseated, it is sufficiently distant from the at least one permanent magnet that it applies little force to the armature. However, when a pulse of power is applied to the solenoid coil the armature is moved to the latched position, sufficiently close to the at least one permanent magnet that the armature is held in place. The armature remains seated in the latched position until a pulse of power is applied to the solenoid coil that generates a relatively strong opposing magnetic field, which neutralizes the latching magnetic field and allows a spring to drive the armature back to the unlatched position. Thus, a magnetically latching solenoid, unlike typical solenoids, does not require power to hold the armature in either position, but does require power to actuate the armature in both directions. While the preferred embodiment employs a magnetically latching solenoid valve, it will be appreciated that any suitable electrically operable valve can be used in series with the manual valve. For example, any type of solenoid valve can be used.

Illustratively, the electrically operable valve is relatively slow-opening and -closing, in order to reduce pressure spikes,

known as “water hammer,” and undesirable splashing. On the other hand, the valve should not open or close so slowly as to be irritating to the user. It has been determined that a valve opening or closing period of at least 0.5 seconds sufficiently suppresses water hammer and splashing.

Referring initially to FIGS. 1 and 2, an illustrative electronic faucet system 100 is shown fluidly coupled to a hot water source 101A and a cold water source 101B. Faucet system 100 includes a spout assembly 102 and a valve body assembly 104 mounted to a sink deck 105. As explained in more detail herein and in U.S. patent application Ser. No. 11/326,989, filed Jan. 5, 2006, entitled “Position-Sensing Detector Arrangement For Controlling A Faucet,” the disclosure of which is expressly incorporated by reference herein, spout assembly 102 illustratively includes several electronic sensors. More particularly, spout assembly 102 illustratively includes a sensor assembly 103 having an infrared sensor 103A generally in an upper portion 106 of spout assembly 102 to detect the presence of an object, such as a user’s hands. Sensor assembly 103 further illustratively includes a Hall effect sensor positioned in upper portion 106 to detect when a pull-out or pull-down spray head 108 is spaced apart from upper portion 106, for example when a user is directing water flow to desired objects within a sink basin 109. Sensor assembly 103 additionally illustratively includes a touch control, such as a capacitance touch sensor 103B wherein fluid flow from spout assembly 102 may be activated by the user touching spout assembly 102. Additional sensors or electronic devices may be positioned within or attached to spout assembly 102.

Due to the presence of electronics (such as the described sensors) generally within upper portion 106, a spout control electrical cable 120 is contained within a delivery spout 110 of spout assembly 102 and provides electrical communication between sensor assembly 103 and a controller 116. Illustratively, controller 116 includes a battery compartment 117 operably coupled to a logical control unit 119. Additional details of the controller 116 are provided in one or more of the Related Applications, including U.S. patent application Ser. No. 11/324,901, filed Jan. 4, 2006, entitled “Battery Box Assembly,” the disclosure of which is expressly incorporated by reference herein.

Valve body assembly 104 also illustratively includes several sensors as explained in more detail in one or more of the Related Applications including U.S. patent application Ser. No. 11/326,986, filed Jan. 5, 2006, entitled “Valve Body Assembly With Electronic Switching,” the disclosure of which is expressly incorporated by reference herein. Valve body assembly 104 illustratively includes a conventional manual valve member (such as a mixing ball or disc) to provide for the manual control of the flow and temperature of water in response to manual manipulation of a handle 118 supported for movement relative to a holder 114. A Hall effect sensor 104A is illustratively positioned in holder 114 to detect a position of the manual valve member, and hence, the handle 118. Valve body assembly 104 further illustratively includes a capacitance touch sensor 104B wherein fluid flow from spout assembly 102 may be activated by the user touching valve body assembly 104. Additional sensors or electronic devices may be positioned within or attached to valve body assembly 104. Due to the presence of electronics (such as the described sensors) generally within holder 114, a valve control electrical cable 130 is contained within holder 114 and provides electrical communication with controller 116.

With further reference to FIG. 2, the faucet system 100 is in fluid communication with hot water source 101A and cold water source 101B. The valve body assembly 104 illustratively

mixes hot water from the hot water source 101 and cold water from the cold water source 101 to supply a mixed water to an actuator driven valve 132 through a mixed water conduit 131. Illustratively, the actuator driven valve 132 comprises a conventional magnetically latching solenoid valve of the type available from R.P.E. of Italy. The actuator driven valve 132 is controlled by the controller 116 through an electrical cable 128 and, as such, controls the flow of mixed water supplied to the spout assembly 102. As shown in FIGS. 1 and 2, the valves 104 and 132 are arranged in series and are fluidly coupled by mixed water conduit 131. The spout assembly 102 is configured to dispense mixed water through spray head 108 and into conventional sink basin 109.

As shown in FIGS. 1 and 2, when the actuator driven valve 132 is open, the faucet system 100 may be operated in a conventional manner, i.e., in a manual control mode through operation of the handle 118 and the manual valve member of valve body assembly 104. Conversely, when the manually controlled valve body assembly 104 is set to select a water temperature and flow rate, the actuator driven valve 132 can be touch controlled, or activated by proximity sensors when an object (such as a user’s hands) are within a detection zone to toggle water flow on and off.

In an illustrative embodiment, the actuator driven valve 132 is controlled by electronic circuitry within control unit 119 that implements logical control of the faucet assembly 100. This logical control includes at least two functional modes: a manual mode, wherein the actuator driven valve 132 remains open, and a hands-free mode, wherein the actuator driven valve 132 is toggled in response to signals from a proximity sensor. Thus, in the manual mode, the faucet assembly 100 is controlled by the position of the handle 118 in a manner similar to a conventional faucet, while in the hands-free mode, the flow is toggled on and off in response to the proximity sensor (while the flow temperature and rate are still controlled by the handle 118 position). The logical control may also include a further functional mode: a touch mode such that tapping of one of the handle 118 and the spout 110 toggles water flow on and off. As further detailed herein, tapping is illustratively defined as a touch by a user having a duration of less than approximately 350 milliseconds and greater than approximately 50 milliseconds. Grasping, in turn, is defined as a user touch having a duration of more than approximately 350 milliseconds. In one illustrative embodiment of the touch mode, tapping either the handle 118 and the spout 110 or a grasping of the handle 118 activates actuator driven valve 132, while grasping the spout 110 alone has no effect.

Illustratively, the faucet assembly 100 is set to operate in a hands-free mode by user interaction, for example by input from a push-button, by input from a strain gauge or a piezo-electric sensor incorporated into a portion of the faucet assembly 100, such as the spout assembly 102, or by input from a capacitive touch button or other capacitive touch detector. It will be appreciated that a touch control, whether implemented with a strain gauge or a capacitive touch-sensor can respond to contact between a user and the handle 118 that is insufficient to change a position of the handle 118.

The capacitive touch control 103B may be incorporated into the spout assembly 102 of the faucet assembly 100, as taught by U.S. Pat. No. 6,962,168, entitled “Capacitive Touch On/Off Control For An Automatic Residential Faucet,” the disclosure of which is expressly incorporated by reference herein. In certain illustrative embodiments, the same mode-selector can be used to return the faucet assembly 100 from hands-free mode to manual mode. In certain of these illustrative embodiments, as detailed herein, a touch-sensor 104B is

also incorporated into the handle **118**. In such illustrative embodiments, the two touch controls can either operate independently (i.e. mode can be changed by touching either one of the touch controls), or together, so that the mode is changed only when both touch controls are simultaneously touched.

More particularly, in one illustrative embodiment, the mode of the logical control may be changed by simultaneously grasping the spout **110** and tapping the handle **118**. In the illustrative embodiment, the mode is toggled from hands free on (i.e., proximity sensor active) to hands free off (i.e., proximity sensor inactive) by simultaneously grasping the spout **110** and tapping the handle **118** twice in order to reduce inadvertent mode changes. As detailed above, grasping is defined by a user contact lasting longer than approximately 350 milliseconds, while tapping is defined as user contact lasting less than approximately 350 milliseconds. As such, the threshold value of 350 milliseconds permits the logical control to distinguish between these two types of contact with a user. However, in other embodiments this value may be different, for example it may be equal to 250 milliseconds.

In certain alternative embodiments, once placed in hands-free mode the faucet assembly **100** can be returned to manual mode simply by returning the manual faucet control handle **118** to a closed position. In addition, in certain illustrative embodiments the faucet assembly **100** returns to manual mode after some period of time, such as 20 minutes, without user intervention. This time-out feature may be useful for applications in which power is supplied by batteries, because it preserves battery life. In one illustrative embodiment, once the hands-free mode is activated, the actuator driven valve **132** is closed, stopping the water flow. This state is the hands-free standby state, in which water flow will be activated by a proximity detector. The manual valve handle **118** preferably remains in the open position. In other words, the manual valve body assembly **104** remains open, so that flow is halted only by the actuator driven valve **132**.

In the hands-free standby state, objects positioned within the sensor's trigger zone cause the faucet assembly **100** to enter the hands-free active state, wherein the actuator driven valve **132** is opened, thus permitting the water to flow. The faucet assembly **100** remains in hands-free active mode, and the actuator driven valve **132** remains open, as long as objects are detected within the sensor's trigger zone. When objects are no longer detected in the sensor's trigger zone, the faucet assembly **100** returns to hands-free standby mode, and the actuator driven valve **132** closes.

It will be appreciated that water flow is important while a user is attempting to adjust the flow rate or temperature. More particularly, the user observes these properties as they are adjusted, in effect completing a feedback loop. Thus, adjustment of the flow properties is another case in which water flow is preferably activated without requiring the user to place his or her hands or an object in the trigger zone. Therefore, in the illustrative embodiment, when the faucet assembly **100** is in standby hands-free mode, the faucet assembly **100** switches to active hands-free mode, and the actuator driven valve **132** is opened, whenever the manual control handle **118** is touched.

In certain alternative embodiments, when the handle **118** is touched while in hands-free mode, the faucet assembly **100** switches to manual mode, which will, of course, also result in activating the water flow (unless the handle is closed), as well as the deactivation of the proximity sensor. If the user wishes to then return to hands-free mode, he or she may reactivate it in the usual way, such as by a touch control.

In the illustrative embodiment, the faucet assembly **100** does not immediately enter the hands-free mode when the

manual valve body assembly **104** is opened and released. Instead, the faucet assembly **100** enters a "quasi-hands-free" state, in which the faucet assembly **100** continues to be manually controlled, and the actuator driven valve **132** remains open. This quasi-hands-free state persists as long as the proximity sensor does not detect the presence of an object within the sensor's trigger zone. This allows the faucet assembly **100** to function as a normal manual valve when initially operated, but to switch modes to hands-free automatically when sensing the presence of an object within the trigger zone. The advantage of this quasi-hands-free mode is that the faucet assembly **100** can be operated as a conventional manual faucet without the necessity of manually selecting the manual mode. This is valuable, for example, in single-use activations such as getting a glass of water or when guests use the faucet assembly **100**. In these embodiments, when the user initially opens the faucet assembly **100** and adjusts the water temperature or flow rate and then releases the handle **118**, the water does not immediately shut off, thereby frustrating the user's attempt to operate the faucet assembly **100** as a manual faucet. After the user has adjusted the flow, and places an object within the faucet assembly's detection zone, the faucet assembly **100** will then enter hands-free mode.

Because the behavior of the faucet assembly **100** in response to its various input devices is a function of the mode it is presently in, illustratively, the faucet assembly **100** includes some type of low-power mode indicator **134** to identify its current mode. Appropriate indicators include LEDs (light emitting diodes), LCDs (liquid crystal displays), or a magnetically latching mechanical indicator. In certain embodiments, the mode indicator **134** may simply be a single bit indicator (such as a single LED) that is activated when the faucet assembly **100** is in hands-free mode. Alternatively, the mode indicator **134** may include a separate bit display for each possible mode. In still other embodiments, the mode indicator **134** may indicate mode in some other way, such as a multi-color LED, in which one color indicates hands-free mode, and one or more other colors indicate other modes. Further, and as detailed herein, transition between modes may illustratively be indicated by an audio output.

Illustratively, the mode indicator **134** comprises a reflector cooperating with a light pipe (not shown) which is configured to assist in directing light from an LED to a forward projecting lens in the manner detailed U.S. patent application Ser. No. 11/325,128, filed Jan. 4, 2006, entitled "Spout Assembly For An Electronic Faucet," which has been incorporated by reference herein. The mode indicator **134** is operably coupled to the logical control **119**. The logical control **119** provides several different operational states for the mode indicator **134**. In a first operational state, which is illustratively the default state, the mode indicator **134** provides a blue light to indicate that the proximity sensor is active thereby providing hands free operation, and provides a red light to indicate a low battery condition. In a second operational state, which is a hands-free flash state, the mode indicator **134** provides a flashing blue light when the proximity sensor is active, provides a solid blue light when water is running due to hands free activation, and provides a magenta color when water is flowing due to touch activation. In a third operational state, all mode indicator functions are disabled, with the exception of a red light to indicate low battery. In a fourth operational state, which is a debug state, the mode indicator **134** provides a solid blue light when the proximity sensor is active, provides a flashing magenta color when a spout touch is sensed, provides a solid magenta color when a valve touch is sensed, provides a solid red color when the actuator driven valve **132** is activated, and provides a flashing red light when the pull

11

down sensor, as described herein, is activated. In a fifth operational state, which is a show room state, the mode indicator 134 provides a solid blue light whenever water should be flowing.

As noted above, an audio output may be provided to indicate transition between modes. More particularly, an audio device, illustratively a speaker 136, is operably coupled to the logical control 119 and is configured to provide an audible indication of transition between modes. In one illustrative embodiment, the speaker 136 provides an ascending tone when the logical control 119 transitions from a hands free off mode (i.e., proximity sensor is inactive) to a hands free on mode (i.e., proximity sensor is active). Similarly, the audio speaker 136 provides a descending tone when the logical control 119 transitions from the hands free on mode to the hands free off mode.

The speaker 136 may also provide audible indications for other system conditions. For example, the speaker 136 may provide an audible tone for a low battery condition. The speaker 136 may also provide a distinct tone upon initial start up of the system.

When a user is finished using the faucet assembly 100, the faucet assembly 100 is illustratively powered down and returned to a baseline state. Powering down provides power savings, which makes it more feasible to operate the faucet assembly 100 from battery power. Returning the faucet assembly 100 to a baseline state is helpful because it gives predictable behavior when the user first begins using the faucet assembly 100 in a particular period of operation. Preferably, the baseline state is the manual mode, since the next user of the faucet assembly 100 might not be familiar with the hands-free operation. Illustratively, a user is able to power down the faucet assembly 100 and return it to the manual, baseline mode simply by returning the manual handle 118 to the closed position, because this is a reflexive and intuitive action for users.

As a consequence, the illustrative embodiment faucet assembly 100 is configured to sense whether the handle 118 is in the closed position. It will be appreciated that this can be accomplished directly, via a sensor in the valve body assembly 104 that detects when the manual valve member is closed, such as by including a small magnet in the handle 118, and an appropriately positioned Hall effect sensor. Alternatively, the handle position can be observed indirectly, for example by measuring water pressure above and below the manual valve, or with a commercial flow sensor. However, it will be appreciated that this inference (that the handle 118 is in a closed position) is only valid if the electrically operable valve is open. It will be appreciated that, because the actuator driven valve 132 is controlled electronically, this is easily tracked by the controller 116. Thus, in the illustrative embodiment, the faucet assembly 100 is returned to manual mode when both the actuator driven valve 132 is open and water is not flowing through the faucet assembly 100.

Illustratively, the faucet assembly 100 also includes a “watchdog” timer, which automatically closes the actuator driven valve 132 after a certain period of time, in order to prevent overflowing or flooding. In certain of these illustrative embodiments, normal operation is resumed once an object is no longer detected in the sensor’s trigger zone. In certain other illustrative embodiments, normal operation is resumed once the manual valve body assembly 104 is closed. In still other illustrative embodiments, normal operation is resumed in either event. In those illustrative embodiments including a hands-free mode indicator 134, the indicator is flashed, or otherwise controlled to indicate the time-out condition.

12

In addition to the various power-saving measures described above, the illustrative embodiment also includes an output mechanism that alerts users when batter power is low. It will be appreciated that any suitable output mechanism may be used, but illustratively mode indicator 134 and audio speaker 136 are used.

FIGS. 4A and 4B are a flowchart illustrating the logical control 119 for a preferred embodiment faucet according to the present invention. The logical control 119 begins each use session at 200, when the manual handle 118 is used to open the manual valve 104. At this time, the faucet is in the manual mode (which fact will be displayed by the mode indicator 134, in those embodiments wherein the mode sensor does not simply activate to indicate hands-free mode). At 214 the mode selectors, including the touch sensor in the spout and the touch-button, are monitored for instructions from the user to enter hands-free mode. At 218 it is determined whether the hands-free mode has been enabled. If not, the logical control 119 returns to 200. If at 218 it is determined that the hands-free mode has been enabled, at 222 the flow sensor is monitored to determine whether the manual valve is open. At 226 it is determined whether the manual valve 104 is open. If not, the logical control 119 returns to 214. If at 226 it is determined that the manual valve 104 is open, hands-free mode is activated at 230.

At 230, hands-free mode is activated by powering up the proximity sensor, initializing and closing the electrically operable valve 132 (thereby shutting off water flow), activating the mode indicator 134 to display hands-free mode, and initializing the hands-free timer. At this time, the faucet is in hands-free standby mode.

At 234 the mode selectors are monitored for instructions to return to manual mode. At 238, it is determined whether manual mode has been enabled. If so, at 242 it is determined whether the electrically operable valve 132 is open. If at 238 it is determined that—manual mode has not been enabled, at 246 the manual handle position is sensed, and at 254 it is determined whether the manual valve 104 is open. If not, at 242 it is determined whether the electrically operable valve 132 is open.

If at 242 it is determined that the electrically operable valve 132 is closed (a “No” result), at 262 the solenoid is opened, and the mode indicator 134 is set to no longer display hands-free mode. If at 242 it is determined that the electrically operable valve 132 is open, or after it is opened at 262, then at 266 the proximity sensor is powered down and the hands-free and watchdog timers are reset. At this time the faucet is in manual mode, and the logical control 119 returns to 200.

If at 254 it is determined that the manual valve 104 is open, then at 258 the proximity sensor is monitored. At 272 it is determined whether the proximity detector has detected an object that should activate water flow. If not, at 276 it is determined whether the solenoid is closed. If at 276 it is determined that the solenoid is closed, at 278 it is determined whether the hands-free timer has expired. If at 278 the hands-free timer has not expired, the logical control 119 returns to 234; otherwise it proceeds to 280, where the solenoid is closed, and the mode indicator 134 is activated to indicate the timeout condition, after which the logical control 119 passes to 266. If at 276 it is determined that the solenoid is not closed, then at 282 the solenoid is closed, the watchdog timer is reset, and the hands-free timer is started, and the logical control 119 then returns to 234.

If at 272 it is determined that an object has been detected which requires that water flow be started, then at 284 it is determined whether the electrically operable valve 132 is open. If not, at 286 the solenoid is opened, the watchdog timer

13

is started, and the hands-free timer is restarted. Then, at **288** the manual valve status is sensed. At **290** it is determined whether the manual valve **104** is open. If so, the logical control returns to **234**. Otherwise, at **292** the mode indicator is activated to indicate that the faucet is no longer in hands-free mode, and the logical control **119** then passes to **266**.

If at **284** it is determined that the electrically operable valve **132** is open, then at **294** the manual valve status is sensed. At **296** it is determined whether the manual valve **104** is open. If not, the logical control **119** proceeds to **292**. If at **296** it is determined that the manual valve **104** is open, then at **298** it is determined whether the watchdog timer has expired. If not, the logical control **119** returns to **234**, but if so, the logical control proceeds to **280**.

In the illustrative embodiment the spout of the faucet is a “pull-down” spout. Those skilled in the art will appreciate that a pull-down spout is a spout that includes an extendible hose that connects it to the valve assembly, thereby permitting the spout to be pulled out from its rest position, where it can be used similarly to a garden hose, to direct water as the user wishes. In the preferred embodiment, when the pull-down spout is extended the faucet the electrically operable valve is automatically opened, so that water flow is controlled by the manual handle. In certain embodiments, this is effected by returning the faucet to manual mode. In certain other embodiments, though, when the spout is retracted the faucet resumes hands-free operation (assuming it was in hands-free mode when the spout was extended). Thus, in these embodiments, when the spout is extended the faucet effectively enters another mode. Note that this mode need not be distinguished from the hands-free mode by the mode indicator, though, since its presence will be obvious and intuitively understood because of the extended spout. Preferably, the electrically operable valve can be toggled by the tap control during this extended-spout mode.

In the illustrative embodiment, the automatic faucet detects that the pull-down spout has been pulled down using Hall-Effect sensors. However, it will be appreciated that any suitable means of detecting that the pull-down spout has been extended may be used.

Another embodiment of the present invention is illustrated in FIGS. **5** and **6**. In this embodiment, a sensor, illustratively a capacitive sensor, is provided for use with a single hole mount faucet **301**. While a capacitive sensor is shown in this embodiment for use in connection with a capacitive coupling, a resistance sensor may also be used in connection with a resistive coupling, as further detailed below. In the illustrated embodiment of FIG. **5**, a oscillator integrated circuit such as, for example, a **555** timer **300** is used as the capacitive sensor. Timer **300** may be a **IMC 7555 CBAZ** chip. It is understood that other types of capacitive sensors may also be used in accordance with the present invention. Pins of the timer **300** are shown in FIG. **5**.

In the illustrated embodiment, pin **1** of timer **300** is coupled to earth ground and to a battery power source ground as illustrated at block **302**. An output of timer **300** is coupled to a controller **304** which is similar to controller **116** discussed above. Pin **2** of timer **300** is coupled through a **1 nF** capacitor **306** to an electrode **308**. Electrode **308** is coupled to the faucet body hub **310**. It should be appreciated that the faucet body hub **310** itself may comprise the electrode **308**. As further detailed below, faucet body hub **310** is also electrically coupled to a manual valve handle **312**, for example by metal-to-metal contact between the handle **312** and the hub **310**. Manual valve handle **312** is movably coupled to the faucet body hub **310** in a conventional manner to control water flow. Since the manual valve handle **312** and the faucet body hub

14

310 are electrically connected, the electrode **308** may also be coupled to the manual valve handle **312**, if desired. Again, electrode **308** may comprise the manual valve handle **312** itself.

As further detailed below, spout **314** is capacitively coupled to faucet body hub **310** by an insulator **316**. In one embodiment, such as for a kitchen faucet, the spout **314** is rotatable relative to the faucet body hub **310**. In other embodiments, the spout **314** may be fixed relative to the faucet body hub **310**. Spout **314** may include a pull-out or pull-down spray head **318** which is electrically isolated from the spout **314**.

The faucet body hub **310** provides sufficient capacitance to earth ground for the timer **300** to oscillate. As further discussed herein, the manual valve handle **312** is electrically connected to the faucet body hub **310**. The spout **314** is capacitively coupled to the body hub **310** by insulator **316** to provide approximately a **100 pF** capacitance. When the manual valve handle **312** is touched by a user's hand, the capacitance to earth ground is directly coupled. The capacitive sensor **300** therefore detects a larger capacitance difference when the handle **312** is touched by a user compared to when the spout **314** is touched. This results in a significant frequency shift when the manual valve handle **312** is touched by a user's hand. However, when the same user touches the spout **314**, the frequency shift is substantially lower. For example, the frequency shift may be over **50%** lower. By measuring the frequency shift compared to a baseline frequency, the controller **304** can detect where the faucet **301** is touched and how long the faucet **301** is touched to enable the controller to make water activation decisions as discussed herein.

FIG. **6** illustrates an output signal from pin **3** of timer **300** which is supplied to controller **304**. The controller **304** can determine whether the manual valve handle **312** is tapped (short duration, lower frequency) or grabbed (long duration, lower frequency) and whether the spout **314** is tapped (short duration, higher frequency) or grabbed (long duration, higher frequency). The controller **304** may use this information to control operation of the faucet **301**, and more particularly of the electrically operable valve **307**, in different modes. The embodiment of FIGS. **5** and **6** may also be used with a proximity sensor (not shown), if desired, for a hands free mode.

FIG. **7** shows illustrative single hole mount faucet **301** including faucet body hub **310** having a base **309** formed of an electrically conductive material, illustratively brass or zinc with a chrome plated finish. The hub **310** also includes an upwardly extending inner hub or member **320** formed of an electrically conductive material, illustratively brass. Inner member **320** is illustratively threadably coupled to base **309**. Base **309** is coupled to a sink deck **313** through a mounting assembly **311**. The mounting assembly **311** includes upper and lower members **315** and **317** which clamp faucet **301** to the sink deck **313**. Upper and lower members **315** and **317** illustratively electrically isolate faucet **301** from sink deck **313** by the use of electrically isolating materials, such as thermoplastics.

A nut **319** threadably engages a shank **321** coupled to base **309** to move lower member **317** toward sink deck **313**. Sensor **300** is illustratively electrically coupled to nut **319** which, in turn, is electrically coupled to base **309** through shank **321**. Inner member **320** is illustratively concentrically received within a lower end **322** of spout **314**. Spout **314** is also formed of an electrically conductive material, and is illustratively either a mechanically formed or hydroformed brass tube with a chrome plated or PVD finished outer surface.

With further reference to FIGS. **7** and **8**, insulator **316** illustratively comprises a substantially cylindrical sleeve **324**

15

having a side wall 325 which defines an annular space or gap 326 between an outer surface 328 of inner member 320 of hub 310 and an inner surface 330 of spout 314. Upper end of sleeve 324 includes a locating ring 332, and lower end of sleeve 324 includes an insulating flange 334. Sleeve 324 is formed of an electrically insulating material, illustratively having a permittivity or dielectric constant of between about 3.5 to 4.0 when it defines a gap 326 of about 0.05 inches, to define the desired capacitance value as further detailed below. In one illustrative embodiment, sleeve 324 is formed of a thermoplastic, and more particularly from a polybutylene terephthalate (PBT), such as Celenex PBT 2002. Side wall 325 of sleeve 324 prevents the spout 314 from coming into electrical contact with the inner member 320 of hub 310, while flange 334 prevents spout 314 from coming into electrical contact with the upper end 335 of base 309 of hub 310.

Side wall 325 of sleeve 324 includes an undercut or annular groove 336 which receives an annular protuberance or ridge 338 formed on outer surface of inner member 320. In one illustrative embodiment, ridge 338 snaps into groove 336 to couple inner member 320 to sleeve 324 and prevent vertical disassembly thereof.

Flange 334 of sleeve 324 provides a spacing or gap 340, illustratively about 0.035 inches to reduce the effect of water droplets bridging upper end of base 309 and lower end of spout 314. Upper spacing 342a between flange 334 and spout 314, and lower spacing 342b between flange 334 and base 309 creates a capillary action that dissipates water droplets.

A friction spacer 344 is positioned intermediate insulator sleeve 324 and spout 314 to prevent undesired movement or "wobbling" therebetween. Friction spacer 344 is received within an annular recess 345 of sleeve 324 and is illustratively formed of an electrically non-conductive material, such as molded thermoplastic. In one embodiment, spacer 344 is formed of Celenex PBT 2002.

As detailed above, spout 314 is capacitively coupled to faucet hub 310 for the purpose of touch differentiation. Spacing between spout 314 and hub 310 creates a capacitive coupling therebetween. This capacitive coupling allows for differentiation between contact with spout 314 and contact with hub 310.

With reference now to FIGS. 9 and 10, handle 312 includes a handle body 346 operably coupled to a manual valve cartridge 348. Handle body 346 is illustratively formed of an electrically conductive material, such as die cast zinc with a chrome plated or PVD finished surface. Valve cartridge 348 may be of conventional design and illustratively includes a valve stem 350 operably coupled to valve members (not shown) to control the flow of hot and cold water therethrough. In the illustrative embodiment, valve cartridge 348 includes a plastic housing 352 receiving the valve members, illustratively ceramic discs, and is therefore electrically non-conductive. Stem 350 is illustratively received with a receiving bore 351 of the body 346 and fixed thereto by a set screw 354. A plug 355 covers the opening for set screw 354. Stem 350 is illustratively formed of an electrically conductive material, illustratively a metal.

A user input member, illustratively a handle blade 357, is operably coupled to handle body 346. In one illustrative embodiment, a fastener, such as a screw 359, couples handle blade 357 to handle body 386.

Valve cartridge 348 is received within a valve receiving bore 356 formed within base 309 of hub 310. A bonnet nut 358 secures valve cartridge 348 within receiving bore 356. More particularly, external threads 360 engage internal threads 362 of the receiving bore 356. Bonnet nut 358 is illustratively formed of an electrically conductive material,

16

such as brass. A bonnet 364 receives bonnet nut 358 and again is illustratively formed of an electrically conductive material, such as brass having a chrome plated or PVD finished outer surface. Bonnet 364 illustratively includes internal threads 366 which engage external threads 368 of bonnet nut 358. A seal, such as o-ring 370, is received intermediate bonnet nut 358 and bonnet 364.

Hot and cold water inlet tubes 363a and 363b are fluidly coupled to manual valve cartridge 348. Mixed water output from valve cartridge 348 is supplied to outlet tube 365, which is fluidly coupled to electrically operable valve 307.

With reference to FIGS. 9-11, a contact assembly 372 provides for an electrical connection between handle 312 and base 309 of hub 310. More particularly, contact assembly 372 is compressed between bonnet nut 358 and handle 312. Contact assembly 372 includes a support 374 including an annular ring or plate 376 and first and second pairs of diametrically opposed, radially outwardly extending tabs 378 and 380. Support 374 is formed of an electrically conductive material, illustratively stainless steel. First pair of tabs 378 include downwardly extending legs 382 which contact bonnet nut 358. Second pair of tabs 380 likewise include downwardly extending legs 384 which contact bonnet nut 358, and also include spring biased fingers 386 which contact bonnet 364.

Contact assembly 372 further includes a resilient contact member, illustratively a conical spring 388 coupled to and extending outwardly from support 374. Spring 388 includes an electrically conductive wire 390, illustratively formed of stainless steel. Valve stem 350 is concentrically received within spring 388 such that the wire 390 does not interfere with its movement. Spring 388 provides electrical communication between bonnet nut 358, bonnet 364 and body 346 of handle 312, while permitting movement of stem 350 relative to bonnet nut 358.

As noted above, pull-down spray head or wand 318 is releasably coupled to outlet end 392 of spout 314 (FIGS. 7 and 12). Spray head 318 illustratively includes a plated metal body 393. In one illustrative embodiment, a magnetic coupler 394 couples spray head 318 to spout 314. As is known, a flexible tube or hose 396 is fluidly coupled to spray head 318 and is received within spout 314. Hose 396 selectively supplies water from manual valve cartridge 348 and electrically operable valve 307 to an outlet 398 of spray head 318.

Spout portion 400 includes a body 404 supporting a magnet 406. Similarly, magnetic coupler 394 includes a spout portion 400 and a spray head portion 402. Spray head portion 402 includes a body 408 supporting a magnet 410. Body 408 illustratively includes a radially outwardly extending insulating flange 411 that electrically insulates the spray head body 393 from the spout 314. As such, user contact with spray head 318 is either not detected by sensor 300 or causes a nominal output signal shift and prevents undesired operation of the electrically operable valve 307. In an alternative embodiment, a direct electrical or an impedance coupling may be provided between spray head 318 and spout 314 such that user contact with the spray head 318 may be detected by sensor 300 to provide additional functionality.

With reference now to FIGS. 13-16, a further illustrative embodiment single hole mount faucet 501 is shown. Many of the components of faucet 501 are similar to those of faucet 301 detailed above. As such, similar components will be identified with like reference numbers.

In faucet 501, insulator 316' has been moved from intermediate hub 310' and spout 314, to intermediate handle blade 357 and handle body 346. An inner member 420 of hub 310' is illustratively concentrically received within lower end 322 of spout 314. Inner member 420 includes a lower contact ring

17

422 configured to electrically contact the upper end of hub base 309. A contact clip 424 is received within an annular groove 426 formed within an upper end of inner member 420. Contact clip 424 is formed of an electrically conductive material, illustratively spring steel, and facilitates electrical contact between hub 310' and spout 314.

As further detailed herein, capacitive coupling provides for touch differentiation between contact or touching of spout 314 and contact or touching of handle 312'. As shown in the illustrative embodiment of FIGS. 15 and 16, insulator 316' is in the form of an adaptor 502 positioned intermediate handle blade 357 and body 346. Adaptor 502 includes arcuate arms 504 extending from opposing sides of a receiving member 506. Receiving member 506 includes a bore 508 receiving an inner stem 510 of handle blade 357. A nut 512 threadably engages inner stem 510 to secure handle 312 to adaptor 502. Adaptor 502, in turn, is secured to handle body 346 through conventional fasteners, such as screws 514. Adaptor 502 is formed of an electrically insulating material, illustratively a thermoplastic polyamide, such as DuPont Zytell 77G33.

Receiving member 506 includes a cylindrical wall 515 that defines a capacitive coupling between handle 312' and body 346. Hub 310' of faucet 501 acts as an electrode and energizes handle body 346 through contact assembly 372. Handle body 346 is capacitively coupled to handle 312 through the dielectric properties of adaptor 502 and the adjacent air gap.

In a further illustrative embodiment, adaptor 502 may be formed of a conductive material that will function as a resistor. As such, adaptor 502 would lower the total impedance between the handle 312 and the handle body 346. Such an arrangement would provide a change in frequency shift or a capacitance change, such that a touch on the handle 312 may be differentiated from a touch on the hub 310 or handle body 346. In another illustrative embodiment as shown in FIG. 17, adaptor 502 may function as an insulator, while a resistor wire 518 resistively couples handle blade 357 and body 346 for the purpose of touch differentiation. Illustratively, resistor wire 518 is a 24 AWG wire with a 1.5 kilohm resistor. A first ring terminal end 520 is coupled to screw 514a while a second ring terminal end 522 is coupled to stem 510 of handle blade 357.

With reference to FIGS. 9-11, in another illustrative embodiment, contact assembly 372 may be formed of conductive material that will function as a resistor. For instance, support 374 may be formed of a carbon filled plastic, such that the handle 312 is resistively coupled to the hub 310. In yet another illustrative embodiment, a wire, with or without a resistor, may couple bonnet nut 358 to handle body 346.

In this application, the term "impedance coupling" is used to describe either a capacitive coupling or a resistive coupling as further described herein. In an illustrated embodiment, the impedance of the impedance coupling selected to match or approximate a characteristic impedance of a human body. Illustratively, a characteristic impedance of a human body is about a 1.5 K ohm resistance in series with about a 100 pF capacitance. The capacitive coupling is therefore set to about 100 pF by selecting the type of dielectric material, the thickness of the dielectric material, and controlling the air gap as discussed above. The resistive coupling is set at about 1.5 K ohms. By matching or approximating the characteristic impedance of a human body, the impedance coupling causes the frequency shift represented as an amplitude change to be reduced by about one half when the faucet component is touched. This drop in frequency shift permits the controller to determine whether the spout or the hub is touched, or whether the handle or the hub is touched, for example.

With reference to FIGS. 18-22, in another illustrative embodiment, a resistor assembly 610 provides a resistive

18

coupling between spout 314 and faucet body hub 310. In one embodiment, the resistive coupling provides a change in frequency shift such that a touch on spout 314 may be differentiated by controller 304 from a touch on hub 310. As illustrated in FIG. 18, resistor assembly 610 includes an insulating adapter 612, a spout contact 614, a hub contact 616, and a resistor 618. Insulating adapter 612 receives a spout stud 620 coupled to base 309 of hub 310. Spout stud 620 is formed of an electrically conductive material, such as brass or other metallic material.

Insulating adapter 612 is formed of a non-conductive material, such as a plastic for example, and is generally cylindrical in shape. An upper wall of adapter 612 includes a plurality of circumferentially spaced lobes 642. A lower wall of adapter 612 includes a plurality of circumferentially spaced vertical ridges or ribs 650. In one embodiment, lobes 642 and ribs 650 provide support for spout 314 to reduce the likelihood of wobble and to improve stability when spout 314 is coupled to hub 310. In particular, an outer diameter of adapter 612 formed by lobes 642 and ribs 650 approximates an inner diameter of spout 314 such that the outer surfaces of lobes 642 and ribs 650 contact the inner surface of spout 314 (see FIG. 20).

Adapter 612 includes a cylindrical inner surface 617 as illustrated in FIG. 20. An inner diameter of adapter 612 formed by inner surface 617 and lobes 642 approximates an outer diameter of stud 620 such that inner surface 617 and the inner surfaces of lobes 642 contact the outer surface of stud 620 (FIGS. 19 and 20) for a secure fit. The base of adapter 612 includes a radial flange 644. In one embodiment, flange 644 electrically isolates spout 314 from hub 310 along the base of adapter 612, as illustrated in FIG. 20.

Referring to FIGS. 18-20, spout contact 614 is retained in an outer groove 622 molded near the upper portion of adapter 612. Hub contact 616 is retained in an inner groove 625 (FIG. 20) molded in the inner surface of the lower portion of the adapter 612. In one embodiment, contacts 614, 616 are made of beryllium copper, stainless steel, or another suitable conductive material.

Referring to FIG. 21, spout contact 614 includes lobes 636a, 636b, 636c that extend radially outwardly from an inner diameter formed by opposing arced sections 634a, 634b, 634c, 634d. A break in spout contact 614 is formed with lipped ends 632, thereby allowing contact 614 to flex for fitting around adapter 612 into outer groove 622. Lobes 636a, 636b, 636c provide multiple surfaces of electrical contact between spout contact 614 and the inner surface of spout 314.

Referring to FIG. 22, hub contact 616 includes lobes 640a, 640b, 640c that extend radially outwardly from an inner diameter formed by opposing arced sections 638a, 638b, 638c, 638d. A break in hub contact 616 is formed with ends 641, thereby allowing hub contact 616 to flex for fitting around stud 620 and into inner groove 625 of adapter 612. Arced sections 638a, 638b, 638c, 638d provide multiple surfaces of electrical contact between hub contact 616 and the outer surface of spout stud 620.

In assembly, an end of stud 620 protrudes past lobes 642 of adapter 612, and a retaining ring 652 is coupled to an outer groove 654 (FIG. 18) formed in the end of stud 620 to facilitate the retention of adapter 612 to stud 620, as illustrated in FIG. 19. As illustrated in FIGS. 20 and 22, adapter 612 further includes a flexible tab 646 that is received by a slot 648 formed in spout 314 to longitudinally and rotationally fix adapter 612 relative to spout 314. Once assembled, tab 646 may be pressed to release spout 314 from adapter 612.

When assembled, sections 634a, 634b, 634c, 634d of spout contact 614 abut outer groove 622 of adapter 612, and the

19

diameter of groove 622 causes lobes 636a, 636b, 636c to contact spout 314. Sections 638a, 638b, 638c, 638d of hub contact 616 are in contact with stud 620, and the outer diameter of stud 620 causes hub contact 616 to flex radially outwardly such that at least lobes 640a, 640c engage inner groove 625 of adapter 612. Resistor 618 is positioned between a pair of ribs 650 of adapter 612, as illustrated in FIG. 19. Leads 628, 626 (FIG. 21) of resistor 618 sit in notches 630 of adapter 612 and contact respective spout and hub contacts 614, 616. In the illustrated embodiment, lead 626 of resistor 618 is positioned in a groove or seat 624 (FIG. 21) of hub contact 616 through a slot 645 formed in adapter 612. Lead 628 is coupled to an end 632 (FIG. 19) of spout contact 614. In one embodiment, leads 628, 626 of resistor 618 are soldered onto respective contacts 614, 616.

In another embodiment, spout and hub contacts 614, 616 each include a hook portion (not shown) that receives the respective lead 628, 626 of resistor 618. The hook portions are then crimped to mechanically and electronically couple the resistor 618 to both contacts 614, 616.

Accordingly, resistor assembly 610 is assembled onto the metallic spout stud 620 which in turn is assembled into hub 310 via a threaded interface. This assembly provides both a mechanical and electrical connection so spout stud 620 is energized to the same level as hub 310. There is a compression between the hub contact 616, the outer surface of spout stud 620, and the inner surface of adapter 612, thereby forcing the opposing sections 638a, 638b, 638c, 638d against the metallic spout stud 620 while at the same time isolating the hub clip from the hub 310 or spout 314. The three lobes 640a, 640b, 640c serve to maintain electrical contact between spout stud 620 and hub contact 616 during rotation or side to side loading of spout 314.

There is also a compression between spout contact 614, the inner diameter of spout 314, and the corresponding groove 622 in adapter 612. This compression forces an electrical contact between spout 314 and the three lobes 636a, 636b, 636c while creating an isolation barrier on the inner diameter of the spout contact 614.

Accordingly, spout contact 614 is electrically connected to spout 314, and hub contact 616 is electrically connected to hub 310. The two contacts 614, 616 are electrically isolated from each other via adapter 612 until the resistor 618 electrically connects the two contacts 614, 616, thereby providing the resistive coupling.

With reference to FIGS. 23-27, in an alternative illustrative embodiment, a resistor assembly 710 provides a resistive coupling between spout 314 and faucet body hub 310. As illustrated in FIG. 23, resistor assembly 710 includes an insulating adapter 712 and a contact ring assembly 714. A spout stud 718 is coupled to hub base 309 and is formed of an electrically conductive material, such as brass or other metallic material.

Insulating adapter 712 is formed of a non-conductive material, such as a plastic, and is generally cylindrical in shape. An upper portion of adapter 712 includes a plurality of circumferentially spaced fingers or tabs 720 extending from a base portion 726. Tabs 720 are flexible and configured to engage spout 314 and spout stud 718. In one embodiment, tabs 720 provide support for spout 314 to reduce the likelihood of wobble and to improve stability when spout 314 is coupled to hub 310. Spout stud 718 includes one or more annular ridges 730 configured to engage adapter 712. Adapter 712 further includes a radial flange 728 formed at the base portion 726. In one embodiment, flange 728 electrically isolates spout 314 from hub 310 along the base portion 726 of adapter 712.

20

Adapter 712 further includes a flexible tab 722 that is received by a corresponding slot 724 formed in spout 314 to longitudinally and rotationally align adapter 712 relative to spout 314. Once assembled, tab 722 may be pressed to release spout 314 from adapter 712.

Referring to FIGS. 26 and 27, contact ring assembly 714 includes a contact ring 734 and a printed circuit board assembly 716. A formed tab 736 of contact ring 734 extends through a slot 738 of printed circuit board assembly 716 and is soldered into place, thereby providing an electrical and mechanical connection between contact ring 734 and circuit board assembly 716. Contact ring 734 includes one or more hub contact surfaces 735 at the inner diameter. Printed circuit board assembly 716 includes a spout contact 740 and a resistor 742 in series with spout contact 740 and contact ring 734. Spout contact 740 is illustratively disk shaped but may be any suitable shape. A break in the contact ring 734 is formed between an end 744 and tab 736, thereby allowing contact ring 734 to flex for fitting around spout stud 718.

Referring to FIGS. 24 and 25, contact ring assembly 714 slides onto spout stud 718 and is retained above the upper annular ridge 730. The hub contact surfaces 735 of contact ring 734 provide radial dynamic contact to spout stud 718. Adapter 712 is slid onto the spout stud 718 over the contact ring 734 such that the printed circuit board assembly 716 is positioned between a pair of tabs 720. In the illustrated embodiment, adapter 712 is secured in a longitudinal position on spout stud 718 via snap fingers 750 engaged with the upper annular ridge 730.

When assembled, contact ring 734 is pressed radially against spout stud 718 by adapter 712, causing contact ring 734 to contact spout stud 718 in multiple locations. Similarly, spout contact 740 of printed circuit board assembly 716 engages the inner surface of spout 314. Accordingly, spout contact 740 is electrically connected to spout 314, and contact ring 734 is electrically connected to hub 310. Resistor 742 electrically connects the two contacts 740, 734, thereby providing the resistive coupling between hub 310 and spout 314.

In one embodiment, the resistance value of resistor 618 (FIG. 18) and resistor 742 (FIG. 27) is between about 1.5 K ohms and 1.8 K ohms to match or approximate the characteristic impedance of a human body, as described herein. Other suitable resistance values may be selected.

While resistor assemblies 610 and 710 are described herein for touch differentiation between spout 314 and hub 310, assemblies 610 and 710 may also be configured for touch differentiation between other faucet components, such as a faucet handle, for example.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the description is to be considered as illustrative and not restrictive in character. Only the preferred embodiments, and such alternative embodiments deemed helpful in further illuminating the preferred embodiment, have been shown and described. It will be appreciated that changes and modifications to the forgoing can be made without departing from the scope of the following claims.

The invention claimed is:

1. A faucet comprising:

a first faucet component;

a second faucet component;

a sensor coupled to at least one of the first faucet component and the second faucet component; and

a resistor assembly coupled to the first faucet component and the second faucet component, the resistor assembly including an insulating adapter,

21

- a first electrical contact coupled to the insulating adapter and in contact with the first faucet component,
 a second electrical contact coupled to the insulating adapter and in contact with the second faucet component, and
 a resistor electrically coupled between the first electrical contact and the second electrical contact.
2. The faucet of claim 1, wherein the first electrical contact is positioned between an inner surface of the insulating adapter and the first faucet component and extends around a majority of the circumference of the first faucet component.
3. The faucet of claim 2, wherein the second electrical contact is positioned between an outer surface of the insulating adapter and the second faucet component and extends around a majority of the circumference of the insulating adapter.
4. The faucet of claim 2, wherein the resistor assembly further includes a printed circuit board, and the resistor and the second electrical contact are mounted to the printed circuit board.
5. The faucet of claim 4, wherein the first electrical contact includes a ring-shaped contact, and the printed circuit board is coupled to the first electrical contact.
6. The faucet of claim 1, wherein the first faucet component includes a faucet body hub, and the second faucet component includes a spout coupled to the faucet body hub.
7. The faucet of claim 6, wherein the faucet body hub includes a spout stud, and the insulating adapter includes a cylindrical wall coupled between the spout and the spout stud.
8. The faucet of claim 1, further including a control unit operably coupled to the sensor, the control unit being configured to determine which of the first faucet component and the second faucet component is touched by a user based on an output signal from the sensor.
9. The faucet of claim 8, wherein a first output signal change is detected by the control unit when the first faucet component is touched by the user, and a second output signal change is detected by the control unit when the second faucet component is touched by the user, the first output signal change being different than the second output signal change.
10. The faucet of claim 1, wherein the sensor includes a capacitive sensor having an electrode coupled to at least one of the first faucet component and the second faucet component.

22

11. A resistor assembly for a faucet, the resistor assembly comprising:
 an insulating adapter including a cylindrical wall, the cylindrical wall forming an opening configured to receive a first faucet component of the faucet;
 a first electrical contact coupled to an inner surface of the insulating adapter and configured to contact the first faucet component;
 a second electrical contact coupled to the insulating adapter and configured to contact a second faucet component of the faucet; and
 a resistor mounted to the insulating adapter and electrically coupled between the first electrical contact and the second electrical contact.
12. The resistor assembly of claim 11, wherein the first electrical contact extends a majority of a circumference of the inner surface of the insulating adapter.
13. The resistor assembly of claim 12, wherein the second electrical contact is coupled to an outer surface of the insulating adapter and extends a majority of a circumference of the outer surface of the insulating adapter.
14. The resistor assembly of claim 12, wherein the resistor assembly further includes a printed circuit board, and the resistor and the second electrical contact are mounted to the printed circuit board.
15. The resistor assembly of claim 14, wherein the first electrical contact includes a ring-shaped contact, and the printed circuit board is coupled to the first electrical contact.
16. The resistor assembly of claim 11, wherein the insulating adapter includes an upper portion and a lower portion, the first electrical contact is coupled to the lower portion, and the second electrical contact is coupled to the upper portion.
17. The resistor assembly of claim 16, wherein the upper portion of the insulating adapter includes a plurality of circumferentially spaced lobes, and the lower portion of the insulating adapter includes a plurality of circumferentially spaced ridges.
18. The resistor assembly of claim 17, wherein the resistor is coupled between at least two of the plurality of circumferentially spaced ridges.
19. The resistor assembly of claim 11, wherein at least one of the first electrical contact and the second electrical contact includes a plurality of lobed portions extending radially outwardly from an inner diameter.

* * * * *